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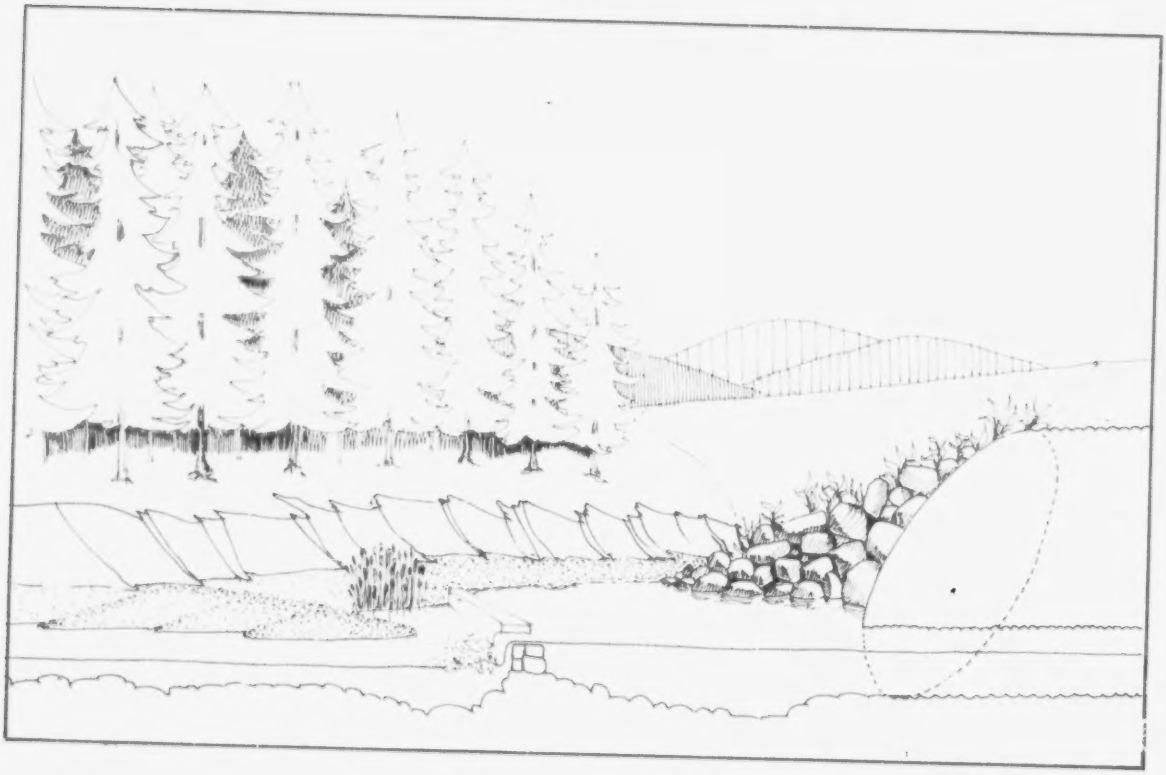
JULY 1982

Handbook for Protection of Fish and Wildlife From Construction of Farm and Forest Roads



Fish and Wildlife Service
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The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EASTERN ENERGY AND LAND USE TEAM
Route 3, Box 44
Kearneysville, West Virginia 25430

AUG 24 1982

Dear Colleague:

Enclosed is an Eastern Energy and Land Use Team publication entitled, "Handbook for Protection of Fish and Wiidlife From Construction of Farm and Forest Roads; Best Management Practices for Building Activities Associated with the Discharge of Dredged or Fill Material." This document addresses those activities and best management practices pertinent to dredge and fill discharges and common to construction and maintenance of farm and forest roads. Included are best management practices for planning road and facility layout and design, erosion control, construction and maintenance operations, and restoration to natural conditions. This product is intended to assist State and Federal permitting authorities and resource and information/education agencies in providing landowners and road developers with best management practices to protect fish and wildlife resources.

Sincerely,

Edgar A. Pash

Edgar A. Pash
Team Leader, Eastern Energy
and Land Use Team

Enclosure

READEX FICHE best copy available

FWS/OBS-82/18
July 1982

Handbook for Protection of Fish and Wildlife From Construction of Farm and Forest Roads

Best Management Practices for Building Activities Associated with the Discharge of Dredged or Fill Material

by

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Performed for
Eastern Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of Interior
Washington, D.C. 20240

Preface

This document represents the completion of a contract to develop a "Handbook of Fish and Wildlife Best Management Practices for Forest and Farm Roads." The Handbook is published by the Eastern Energy and Land Use Team as part of the Fish and Wildlife Service's technical assistance activities. As such it is intended to:

1. Provide a resource document that will assist State permitting authorities which are planning to assume Clean Water Act (P.L. 95-217) Section 404 permitting responsibilities with implementation of 40 CFR Section 123.92(a)(6) of the Consolidated Permit Regulations; specifically, the identification of best management practices for construction and maintenance of farm or forest roads which assure that flow and circulation patterns as well as chemical and biological characteristics of the navigable waters are not impaired;

2. Assist State and Federal permitting authorities, resource and information and education agencies in providing landowners and farm or forest road developers with support in planning and implementing best management practices which facilitate the protection and propagation of fish and wildlife resources during road construction and maintenance;

3. Guide the planning, construction and maintenance of farm and forest roads to comply with the permit exemption requirements of Section 404(f)(1)(E) of the Clean Water Act of 1977; and

4. Assist the U.S. Army Corps of Engineers and resource agencies during the review of permit applications and other resource development proposals in making practicable recommendations for the proper design of farm and forest roads.

This Handbook does not create regulatory requirements. The ultimate authority on implementation of specific best management practices is either an approved State regulatory agency under the authority of the Clean Water Act or the U.S. Army Corps of Engineers in the absence of an approved state 404 permitting agency.

Users of this Handbook should be aware that, irrespective of the use of best management practices, Section 404(f)(2) of the Clean Water Act specifies that farm and forest roads are not exempt from permit requirements if their construction will result in a loss or change of wetlands or open water or will affect the flow of water through such areas.

In addition, a handbook such as this cannot cover all site-specific situations. Therefore, the appropriate State or Federal permitting authority should be contacted to determine if an exemption is appropriate and what best management practices are necessary when specific activities are being planned. This Handbook includes best management practices with wide applicability; others exist that may be more appropriate for certain situations.

Any suggestions or comments regarding the Handbook should be directed to:

Chief, Division of Ecological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

Summary

Section 404(f) of the Clean Water Act of 1977 exempts the construction or maintenance of farm and forest roads from the need for Section 404 permits providing that:

1. They are not for the purpose of bringing navigable waters into a new use or do not affect the flow or circulation or impair the reach of such areas; and

2. They are constructed and maintained in accordance with best management practices to assure the flow and circulation patterns and chemical and biological characteristics of navigable waters are not impaired and that any adverse effect on the aquatic environment will be otherwise minimized.

States assuming Section 404 permitting responsibilities according to the Consolidated Permit Regulations (40 CFR 123) must include a description of acceptable best management practices (BMPs) for farm and forest roads in their program description. This Handbook describes 54 BMPs that may be incorporated by State agencies into their program descriptions or utilized by Federal and State agencies and private developers in the review of project plans and in the planning, construction, and maintenance of specific projects.

Best management practices for planning road and facility layout and design, erosion control, construction and maintenance operations, and restoration to natural conditions, identified through existing State water quality management plans and management practices of Federal agencies, were evaluated as to their environmental, institutional, technical, and economic effectiveness. Based on the results of the evaluation, BMPs were modified or augmented with other practices to enhance their overall effectiveness and to provide for protection and propagation of fish and wildlife resources. A discussion of purpose, description, performance and limitations is provided for each BMP, and an approach is developed which guides Handbook users in the selection of BMPs applicable to site-specific situations.

Acknowledgements

Several Fish and Wildlife Service personnel provided substantive review of this document, including Gene Whitaker, Dale Hoffman, Steve Oddan, and Felix Smith. Mr. William Davis of the U.S. Environmental Protection Agency also reviewed the document, along with representatives from the U.S. Army Corps of Engineers, the USDA Soil Conservation Service and Forest Service.

Individuals too numerous to mention within the USDA Forest Service provided technical assistance. Additional technical information was provided by the USDA Soil Conservation Service, USDI Bureau of Land Management, U.S. Environmental Protection Agency, and by a wide variety of state agencies including the California Department of Fish and Game, California Water Resources Control Board, Colorado Department of Health, Colorado Water Conservation Board, Colorado Division of Wildlife, Florida Division of Forestry, University of Georgia, Indiana Bureau of Forestry, Maine Land Use Regulation Commission, Michigan Department of Natural Resources, North Carolina Division of Forest Resources, Oregon Department of Forestry, Oregon State University, Washington Department of Natural Resources, Washington Department of Ecology, and West Virginia Office of the State Forester. Dr. George Ice of the National Council of the Paper Industry for Air and Stream Improvement, Inc., provided initial direction regarding locating sources of information at the state level.

Photographs and other illustrations used in the document were graciously provided the the USDA Forest Service, Wisconsin Department of Natural Resources, Indiana Board of Forestry, and Maine Land Use Regulation Commission. Illustrations and photographs were adapted for use in the Handbook by Ms. Betsy Kehoe and Mr. William Reed of Center For Natural Areas.

Ms. Priscilla Slack and Ms. Renee Potosky of Center For Natural Areas proof-edited earlier versions of this document. Ms. Carmen Belanger, with assistance from Ms. Slack, completed the word processing functions. Mr. Phil Williams, also of Center For Natural Areas, assisted by searching for relevant photographs for inclusion into the document. William C. Reed performed the layout and formatting for the Handbook.

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Introduction 1.0

The Clean Water Act of 1977, under Section 404, exempts from regulation by the U.S. Army Corps of Engineers, the discharge of dredged or fill material (Section 404(f)):

> "(1)(E) for the purpose of construction or maintenance of farm roads or forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained, in accordance with best management practices, to assure that flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized;" (emphasis added)

The Act specifically states (Section 404(f)(2)) that the exemption cannot be used for:

> "Any discharge of dredged or fill material into the navigable waters incidental to any activity having as its purpose bringing an area of the navigable waters into a use to which it was not previously subject, where the flow or circulation of navigable waters may be impaired or the reach of such water be reduced, shall be required to have a permit under this section."

The Clean Water Act also provides a vehicle for State assumption of the Federal dredge and fill permit program under Section 404 for eligible waters of the United States. The best management practices (BMPs) necessary to allow the exemption of farm and forest roads must be described in the State's program. Both the Consolidated Permit Regulations (40 CFR 123) for the State assumption program and The U.S. Army Corps of Engineers proposed amendments to the Section 404 permit regulations (45 FR 62949 of September 19, 1980) specify that the BMPs applied to satisfy the requirements of the Act "... shall include the following baseline provisions:

(i) Permanent roads (for farming or forestry activities), temporary access roads (for mining, forestry, or farm purposes) and skid trails (for logging) in waters of the U.S. shall be held to the minimum feasible number, width, and total length consistent with the purpose of specific farming, silvicultural or mining operations, and local topographic and climatic conditions;

(ii) All roads, temporary or permanent, shall be located sufficiently far from streams or other water bodies (except for portions of such roads which must cross water bodies) to minimize discharges of dredged or fill material into waters of the U.S.;

(iii) The road fill shall be bridged, culverted, or otherwise designed to prevent the restriction of expected flood flows;

(iv) The fill shall be properly stabilized and maintained during and following construction to prevent erosion;

(v) Discharges of dredged or fill material into waters of the United States to construct a road fill shall be made in a manner that minimizes the encroachment of trucks, tractors, bulldozers, or other heavy equipment within waters of the United States (including adjacent wetlands) that lie outside the lateral boundaries of the fill itself;

(vi) In designing, constructing, and maintaining roads, vegetative disturbance in the waters of the U.S. shall be kept to a minimum;

(vii) The design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the water body;

(viii) Borrow material shall be taken from upland sources whenever feasible;

(ix) The discharge shall not take, or jeopardize the continued existence of a threatened or endangered species as defined under the Endangered Species Act, or adversely modify or destroy the critical habitat of such species;

1.0 Introduction

(x) Discharges into breeding and nesting areas for migratory waterfowl, spawning areas, and wetlands shall be avoided if practical alternatives exist;

(xi) The discharge shall not be located in the proximity of a public water supply intake;

(xii) The discharge shall not occur in areas of concentrated shellfish production;

(xiii) The discharge shall not occur in a component of the National Wild and Scenic River System;

(xiv) The discharge of material shall consist of suitable material free from toxic pollutants in toxic amounts; and

(xv) All temporary fills shall be removed in their entirety and the area restored to its original elevation.

Construction of farm and forest roads invariably entails some environmental disturbance. However, experience has shown that the magnitude of the disturbance can be kept at a minimum if certain precautions are taken. Furthermore, if incorporated during early planning stages, such precautions often will not materially affect the cost of the project. A great deal of the past environmental damage associated with low-volume road construction has resulted from incomplete knowledge and inadequate planning. The body of the present volume treats in detail various phases and aspects of forest and farm road planning, design, and construction, and focuses attention upon potential environmental damage and methods of circumventing or minimizing this damage.

1.1 Objectives

The objectives of this handbook are to:

1. Provide a resource document that will assist State permitting authorities which are planning to assume Clean Water Act (P.L. 95-217) Section 404 permitting responsibilities with implementation of 40 CFR Section 123.92(a)(6) of the Consolidated Permit Regulations; specifically, the identification of best management practices for construction and maintenance of farm or forest roads which assure that flow and circulation patterns as well as chemical and biological characteristics of the navigable waters are not impaired;

2. Assist State and Federal permitting authorities, resource and information and education agencies in providing landowners and farm or forest road developers with support in planning and implementing best management practices which facilitate the protection and propagation of fish and wildlife resources during road construction and maintenance;

3. Guide the planning, construction and maintenance of farm and forest roads to comply with the permit exemption requirements of Section 404(f)(1)(E) of the Clean Water Act of 1977; and

4. Assist the U.S. Army Corps of Engineers and resource agencies during the review of permit applications and other resource development proposals in making practicable recommendations for the proper design of farm and forest roads.

1.2 Scope

To the extent possible, BMPs are provided so they are adaptable on a National level. This handbook addresses those activities and BMPs pertinent to the discharge of dredged or fill material and common to construction and maintenance of farm or forest roads. Moreover, the document only considers activities which usually can be exempted from individual permitting through BMPs under Section 404(f)(1)(E) of the Clean Water Act. Therefore, activities which might result in impairment of flow

and circulation of waters, e.g., channelization, and thus would require permits under Section 404(f)(2) are not considered. Activities and fish and wildlife impacts that occur within tidal waters are not specifically considered, but most of the general management practices and principles are probably applicable.

The document is specifically oriented to those BMPs useful to control water pollution and protect fish and wildlife from dredge and fill discharges. Thus, many BMPs which could be useful under State nonpoint source pollution control (208) programs are not included within this report. These BMPs predominantly involve the control of drainage, erosion, and water quality effects from upland sources.

Finally, BMPs are presented which address the protection and restoration of fish and wildlife resources to their original, pre-project status. The concepts of habitat and population enhancement and management are not addressed, since these activities are not specifically recognized by the the Clean Water Act.

1.3 Research Methods

This section provides a brief summary of the processes used to compile the Handbook. The reader is urged to consult Appendix A for a complete description of the methods used.

BMPs were identified from a variety of Federal agency (USDA Forest Service and Soil Conservation Service, U.S. Environmental Protection Agency, and USDI Bureau of Land Management and Fish and Wildlife Service) manuals and guidance documents, as well as from existing voluntary and mandatory BMP Programs for selected States. Where necessary, other BMPs were identified through the technical literature.

Each BMP was evaluated by an interdisciplinary team using a standard process that considered environmental impacts, regulatory requirements, site-specific limitations, cost, and technical factors. The evaluation resulted in a determination for each BMP on the following points:

1. Whether or not the BMP had a positive effect on fish and wildlife resources;
2. If the BMP responded to or violated one or more of the baseline provisions in 40 CFR Section 123.92(a)(6); and
3. Whether or not the BMP could be reasonably implemented in the field.

At one point during the study, the BMP system in its entirety was evaluated. Gaps were noted and used as direction for further efforts to identify BMPs.

1.4 Use and Organization of the Handbook

The Handbook is merely intended as a catalog of the most widely applicable practices for the construction and maintenance of farm and forest roads. It may also be used as a catalog of possible options for inclusion in a State's BMP system. As such, the Handbook is not a list of mandates for a 404 Program. Each State or Federal permitting authority can add, delete, or modify the BMPs as they so determine. THE APPROPRIATE STATE OR FEDERAL PERMITTING AUTHORITIES ARE THE RESPONSIBLE AGENCIES FOR DETERMINING THE SPECIFIC BMPS NECESSARY TO OBTAIN EXEMPTION FROM INDIVIDUAL PERMITTING.

Chapters are organized in the chronological order of farm and forest road development, beginning with siting, and followed by design, erosion control, construction, maintenance, and restoration to natural conditions. Within the chapters, each BMP is identified and described as a separate section. Each discussion contains a statement of BMP purpose(s), a description of how to implement the BMP, a discussion of how and to what degree the BMP addresses environmental impacts of road development, a listing of limitations that could affect the practicality and efficacy of the BMP, and references valuable for further information.

The "Purpose" statements are designed to give the reader an initial means of determining whether or not a BMP is of interest. They concentrate on stating what environmental effects or issues are addressed by each BMP. Moreover, they give the reader a means of determining the relationship

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between the BMP and the baseline provisions of the Consolidated Permit Regulations (40 CFR 123.92(a)(6)). A reader who is cognizant of the impacts and issues of concern for a particular program area or project can, by quickly skimming the "Purpose" sections, separate BMPs which do address their concern from practices that do not.

Those readers who are not familiar with the environmental impacts associated with discharge of dredged or fill material from forest and farm road activities can use the impact evaluation matrix (Appendix A; Figure 58) to determine relationships between the physical effects and the biological impacts of discharges of dredged or fill materials. Other references, such as Darnell et al. (1976), can be consulted for description and discussion of the general significance of the effects of construction in waters of the United States.

Once an initial list of potentially applicable BMPs is determined, the remaining sections within each BMP discussion can be used to further evaluate and implement the BMP system. BMPs whose purposes address the issues and impacts at hand are assessed in greater detail through review of "Performance" and "Limitations" discussions to determine the efficacy of the BMP and the practicality of implementing it under the physical and ecological conditions involved in the project or program. The "Description" provides further definition of the BMP, as well as general directions on how to implement it. If further information is needed, the "References" can be consulted in their original form.

For any individual case, no one BMP will effectively resolve all fish and wildlife issues. Therefore, it will be necessary to incorporate a variety of BMPs into a coherent system. Such a system is needed because:

1. Usually more than one type of effect on fish and wildlife is involved;

2. Specific BMPs, although generally useful, may not be applicable to certain site-specific circumstances as described in the "Limitations" sections. Therefore, alternative BMPs should be available to ameliorate fish and wildlife concerns where the original BMPs cannot be used. For example, although bridges are chosen as the most environmentally sound water crossing structure in one BMP (3.2), circumstances do exist that make bridges impractical. In those cases, BMPs for culvert design, construction, and maintenance would be employed; and

3. In many cases, BMPs act synergistically to reduce fish and wildlife impacts. For example, slope angle of fill, mulching, seeding, compacting, and scarifying the fill slope will often reduce water quality effects better when used in combination than when used singly.

Thus, an appropriate BMP system would resolve all fish and wildlife concerns to the fullest extent possible, and would account for the variety of site-specific conditions that could be expected within a program's area and for any one project. Once a preliminary system is determined through the approach described above, it would be prudent to evaluate the program as a whole. In order to do this, the following questions should be answered:

1. Are all environmental effects and issues of concern to the program addressed by the BMP system?

2. Does the BMP system effectively respond to all the baseline provisions of the Consolidated Permit Regulations (40 CFR 123.92(a)(6))?

3. Do sufficient alternative BMPs exist to meet both above items for the full range of site-specific conditions that can be expected?

1.5 Literature Cited

Darnell, F.M., W.E. Pequegnat, B.M. James, F.J. Benson, and R.A. Defenbaugh. 1976. Impacts of construction activities in wetlands of the United States. U.S. Environmental Protection Agency Publ. No. EPA-600/3-76-045. Corvallis, Oregon. 392p.

Avoidance of Wetlands 2.1

Purposes

a) To protect significant fish and wildlife habitat.

b) To avoid difficult road construction and maintenance situations.

Description

Avoid routing roads through, near, or directly upslope of all areas where the water table is usually at or near the surface, or where the land is covered by shallow water. Such areas typically support characteristic wetland plants and/or have hydric soil types. If the substrate is not soil, wetlands are identified as saturated or covered with water at some time during the growing season. Wetlands are of great importance to various wildlife animal species for spawning, cover, feeding, and drinking. In many instances, wetlands have been formally identified as ecologically sensitive areas (BMP 2.7).

In practice, wetlands should be located by using existing data sources and making field inspections of potential routes. Existing data sources include the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI), state wetlands surveys, and topographical maps. When interpreting this information, care must be taken to insure that wetlands identified conform to applicable guidance under dredge and fill regulatory programs.

Two potential sources of confusion exist when applying this information to forest and farm road planning: (1) differences between regulatory and survey definitions of what is a wetland, and (2) wetland inventories being conducted at a scale insufficient to delineate small but productive wetlands.

For example, even though both the applicable regulatory definition of wetland (40 CFR 230.3(r)) and the definition used by the NWI (Cowardin et al. 1979) are based on vegetation type, the determination of whether or not a specific vegetation type is wetland or upland is somewhat subjective. Other surveys use definitions unrelated to vegetation. For example, some states delineate wetlands by soil type, while topographical maps commonly indicate merely the presence of standing water during some seasons.

Moreover, the scale of the inventory somewhat limits delineation. For example, the NWI is mostly limited to wetlands over 10 acres in size (Cowardin et al. 1979), but wetlands under this size would be applicable under dredge and fill regulations.

Therefore, field inspections are commonly necessary to augment existing data sources. Inspections would be conducted prior to road survey, on foot or by boat if necessary. Wetlands identified by either or both methods would be plotted on planning maps as control points, and the road routed around them.

Performance

Wetlands frequently support disproportionately large populations of wildlife and fish (Figure 1). Some wetlands may also exert an inordinate influence on regional hydrological cycles important to wildlife. They may help sustain base flows, moderate peak flows, trap sediment and pollutants (at least temporarily), and diversify the food sources available to fish and wildlife.

If the wetlands inventory is relatively comprehensive and avoidance stipulations are met, the natural functions of wetlands will be protected very effectively and fish and wildlife from a region many times the size of the wetland will benefit.

2.1

Figure 1 **Wetlands support disproportionately large fish and wildlife populations. They should be avoided to the extent possible during road planning. (Photo courtesy of USDA Forest Service).**

Limitations

It would be difficult to meet this BMP completely under the following conditions:

1. Environmentally compatible agricultural or silvicultural practices are being conducted in wetlands (e.g., sound management and harvest of swamp and bog timber);

2. An extremely high degree of interspersion exists between upland and wetland habitats;

3. The wetland is linear in nature and must be crossed; and

4. The only other alternatives involve locating the road on steep, unstable slopes which cannot be stabilized.

In some regions it is virtually impossible to avoid wetlands entirely. In such cases other relevant BMPs should be applied to the fullest

extent and, in some instances, individual wetlands should be ranked according to their relative importance to fish and wildlife.

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2.0 Route and Facility Location Planning

2.2 Ecologically Sensitive Areas

Purpose

Protect areas vital to the welfare of significant regional fish and wildlife resources.

Description

Roads should not be located within areas whose physical or biological systems are significant to fish and wildlife or sensitive to impacts associated with roads. Such areas may include, but are not limited to: some raptor nest sites; big game wintering and migration areas; habitats of rare, threatened, or endangered animals or plants; wading bird rookeries; shorebird roosts; streams and wetlands of known high value e.g., for spawning or migration to priority fishery and waterfowl resources; areas with large concentrations of snags or overmature timber essential to many wildlife species; habitats of species which play a major role in local ecosystem functioning (e.g., beaver in some situations); designated wild and scenic rivers; important shellfish areas; public water supplies; and others (Washington Forest Practice Board 1976).

Information as to the location of such areas can and should be obtained from a variety of sources, including the U.S. Fish and Wildlife Service, state fish and game agencies, state planning offices, state water resource agencies, and others. Several states have a system of water values classification (Appendix B) which can be of much use to the road planner in delineating ecologically important waters. Finally, some private agencies, such as the Nature Conservancy, or the applicable state university may be able to provide assistance.

The road planner should draw ecologically sensitive areas on the planning map. These locations would serve as control points in the planning process. Roads should be routed around these areas.

Performance

If the inventory thoroughly covers spatial and seasonal considerations, and avoidance stipulations are followed, significant ecological resources will be protected very effectively.

Limitations

Boundaries of such areas are often difficult to pinpoint. The inventory process may be costly and time-consuming, depending on extent of existing data and level of comprehensiveness desired. A tradeoff may occur in that the protection of a small but important ecological area may require the loss of a large acreage of habitat of moderate value in order to pragmatically align an alternate route.

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Buffer Strips 2.3

Purposes

a) To use vegetation as a filter for sediment caused by bare road surfaces and cut and fill slopes.

b) To prevent significant temperature alterations in waters by maintaining bank shading.

c) To reduce entry of large organic debris into waters.

d) To preserve riparian wildlife habitat.

Description

For forest roads, a strip of undisturbed vegetation should be left between the road and the water, except at points where the road must cross the water (Figure 2). The toe of the fill slope of permanent roads should not extend into the buffer strip (Kochenderfer 1970, Haussman and Pruett 1978). Likewise, skid roads should not extend into the buffer strip. If harvesting is permitted on a limited basis within the strip, alternative harvesting methods, such as cabling or winching logs out of the strip, should be used. For farm roads, the regulations on operating within the buffer strip would be analagous. However, a need to establish vegetation through seeding and planting (BMP 4.4) might exist.

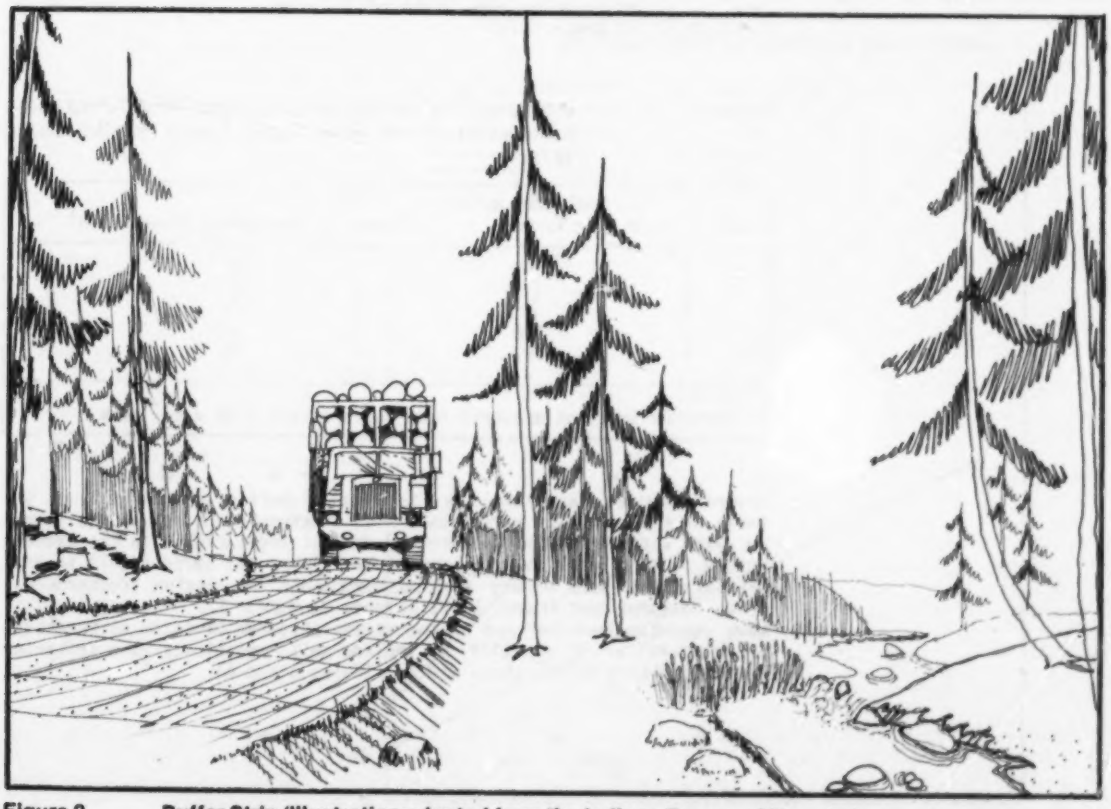

Figure 2 **Buffer Strip (Illustration adapted from the Indiana Bureau of Forestry).**

2.3

To implement a buffer strip BMP, two important decisions must be made:

1. Determination of which waters require the protection of buffer strips; and

2. Establishment of buffer strip widths.

In many cases, buffer strips have been applied to only perennial streams and lakes (Kochenderfer 1970, Haussman and Pruett 1978, Oregon Department of Forestry 1980). However, where water values are high, buffer strips around wetlands and intermittent streams may be appropriate.

In order to establish buffer strip widths for maximum effectiveness, the widths should be linked to site conditions as much as possible. This is especially true in the case of wetlands which have been identified as ecologically important or sensitive. In fact, some agencies (Oregon Department of Forestry 1980, California Coastal Commission 1980) feel that the appropriate buffer strip width should be determined by trained personnel on a case-by-case basis.

Standardized buffer strip widths can be set by using water value criteria (Appendix B) and/or physical conditions of the site. The former case is illustrated by the State of Washington (Table 1; Washington Forest Practice Board 1976).

Table 1. Example of buffer strip width system established using water value criteria (Washington Forest Practice Board 1976).

Water Class	Relative Water Value	Streamside Management Zone Width[1]
1	High	50
2	↓	50
3		25
4		0
5	Low	0

[1]Width in feet, as measured from the ordinary high water mark

Several schemes have been used to develop buffer strip widths on the basis of physical site variables. Most of these are based on the degree to which sediment can be filtered by natural vegetation. In the Eastern United States, guidelines developed by Trimble and Sartz (1957) in West Virginia have been widely applied throughout the region (Kochenderfer 1970, Haussman and Pruett 1978) (Figure 3, Table 2). These guidelines have recently been refined by two states (Florida Division of Forestry, no date; Miller et al. 1979) to include soil erodibility as a criterion for determining buffer strip widths (Tables 3 and 4)

Table 2. **Recommended widths for filter strips between logging roads and streams (Kochenderfer 1970).**

Slope of land between road and stream (%)	Width of filtration strip* (ft.)
0	25
10	45
20	65
30	85
40	105
50	125
60	145
70	165

*In municipal watersheds, these distances should be doubled.

Figure 3 **Relationship between degree of slope and the distance sediment is carried by storm runoff (Trimble and Sartz 1957) for studies in West Virginia.**

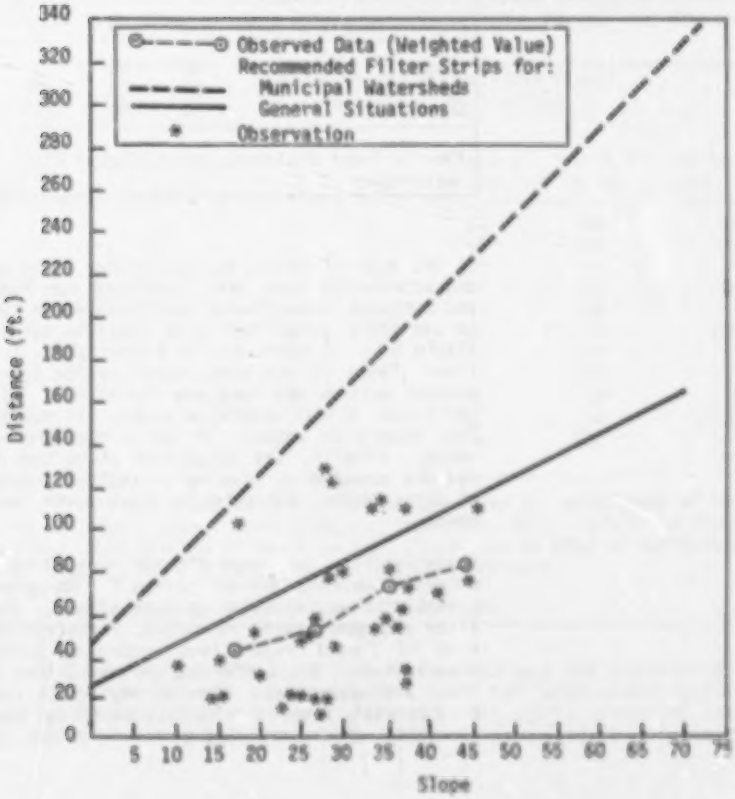

Table 3. **Buffer strip width (in feet) guidelines for Florida (Florida Division of Forestry, no date).***

Soil Erodibility (K Factor)	Percent Slope 0-2	3-7	8-12	13-17	18-22	>22
≤ .20 (Low)	35	45	60	75	90	110
.21-.27 (Moderate)	35	60	75	90	110	140
≥ .28 (High)	35	60	80	100	120	140

*Double these distances for disturbed areas in municipal water supply watersheds.

Table 4. **Buffer strips width (in feet) guidelines for Virginia (Miller *et al.* 1979).***

Erosion Hazard of Soil	Percent Slope 0	10	20	30	40	50	60
Slight	30	55	80	105	130	155	180
Moderate	40	75	100	140	170	200	235
Severe	50	90	130	170	210	250	290

*Double these distances for disturbed areas in municipal water supply watersheds.

In the Western United States, buffer strip guidelines based on physical characteristics have been developed for Forest Service use in Montana and northern Idaho (Packer and Christensen 1964, Packer 1967). In order to use these guidelines, site specific soil group data must be obtained (Table 5). If soils are in either group 2 or group 5, standard guidelines (Table 6) are used, based on the type of obstructions which are present between the road and the stream. If soils are from group 4, an additional 5 feet should be added. If soils are from groups 1 or 3, 10 feet should be added. If soils come from group 6, 24 feet should be added. Finally, the guidelines state that buffer strip widths can be reduced somewhat by placing or replacing obstructions, reducing spacing of cross drains, establishing plant cover, and reducing the width of the road.

Operationally, the road planner must first determine the location of waters requiring buffer strips. Topographic maps and/or wetlands inventories would assist in this effort. The appropriate state agency (fish and game, water resources, forestry) would be contacted to determine if formal regulations regarding buffer strip widths had been promulgated. The buffer strips would then serve as control points in the planning process. When surveying the road, the location of the toe of the fill slope can be estimated by knowing the location of the travelled way and applying geometric guides, such as Megahan (1976).

Table 5. **Forest soil groups in order of (1) decreasing coarseness and increasing detachability of soil on road surfaces and (2) major parent materials in each group (Table from Packer and Christensen 1964).**

Soil Group					
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
hard sediments shale (hard) slate argillite rhyolite rhyolite porphyry limestone (hard)	basalt basalt porphyry quartzite conglomerate gravel	granite sandstone gneiss schist sand	glacial silt shale (soft)	andesite andesite porphyry limestone (soft)	loess

Decreasing coarseness →

Increasing detachability →

Table 6. **Protective strip widths[1] required from the centerlines of roads in order to prevent sediment from reaching sites needing protection (Table from Packer and Christensen 1964).**

	Width of protective strip (feet) by type of obstruction					
Obstruction spacing[2] (feet)	Depressions or mounds	Logs	Rocks	Trees & Stumps	Slash & Brush	Herbaceous vegetation
1	53	55	56	58	59	61
2	55	58	61	64	67	70
3	57	61	65	70	75	79
4	58	64	70	76	82	88
5	59	66	74	81	89	96
6		68	77	86	95	104
7		70	80	91	102	112
8		71	83	95	107	119
9		72	85	99	113	126
10				103	118	133
11				106	122	139
12						145

[1]Figures in this table assume soils from groups 2 and 5, conditions of 30-foot spacing of cross drains, zero distance from cross-drain outlet to first obstruction, zero density of cover on fill slopes and no plan to maintain capacity of obstructions for retarding and trapping sediment.

[2]Refers to the average distance between obstructions.

Performance

The value of a buffer strip for reducing sediment and otherwise protecting fisheries and other aquatic biota has been almost universally recognized. The concept was accepted by all agency directions examined. Moreover, its value to wildlife (Figure 4; Thomas 1979) is becoming more

and more apparent as the importance of riparian habitat is realized (Stauffer and Best 1980; Lyon, in press; Bull 1978; Curtis and Ripley 1975). In individual circumstances, buffer strip effectiveness is strongly correlated to its width. More refined site-specific analysis, rather than simple buffer strip widening, is being recommended by various authors (Wooldridge 1979, Burns 1972).

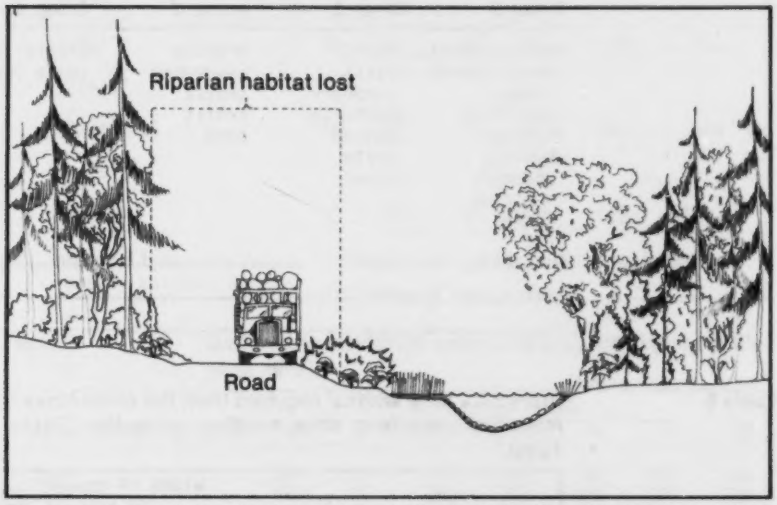

Figure 4 Loss of riparian habitat due to lack of a buffer strip (Thomas 1979).

Limitations

From a regulatory perspective, buffer strips may not be required unless there is a possibility of roadfill material being discharged into waters of the United States.

Topography and soils would present the most severe technical limitations. Steep, narrow canyons with unstable soils are areas where the use of buffer strips would be most restricted. It is recommended that, if possible, these areas be avoided completely.

Institutionally, the costs of implementing a buffer strip are directly proportional to the precision employed in setting strip widths. Operationally, costs are borne through either (a) eliminating buffer strip areas from production, or (b) using alternative timber harvesting procedures (Dykstra and Froelich 1976).

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Stream Crossings 2.4

Purpose

To reduce erosion, sedimentation, flow alterations, and riparian habitat loss.

Description

Stream crossings should be kept to a minimum. During the road planning process, this can be accomplished by overlaying tracing paper or plastic over a topographic map or other maps. Alternative road locations can then be sketched and evaluated on the basis of number of stream crossings and other criteria (Figure 5; Kent 1978). When streams must be crossed, the following criteria should be applied for determining exact location (Figure 6).

1. Crossings should be perpendicular to the stream flow, rather than at an angle;
2. The stream bed should be straight and of uniform profile above, at, and below the crossing;
3. The alignment of stream and road should be straight in all four directions;
4. The crossing should be where the stream is relatively narrow with low banks and firm, rocky soil; and
5. Deeply cut stream banks and soft, muddy soil should be avoided.

Performance

These stream crossing criteria have been accepted widely, and included in management direction for the USDA Forest Service as well as the states of Washington, Indiana, Georgia, Florida, North Carolina, West Virginia, and Oregon. Using a minimum number of crossings will obviously reduce all effects to the stream. Having the crossing perpendicular serves to reduce the amount of area disturbed and reduces flow alteration. Streambed and streambank criteria effectively meet erosion and sedimentation concerns.

Limitations

Situations may exist where appropriate stream bank and streambed criteria may not exist. Moreover, if appropriate conditions are rare, extensive rerouting of the road system to find the right stream crossing location may unnecessarily lengthen the road system. Finally, where the otherwise appropriate location would adversely affect an environmentally sensitive area (BMP 2.2), the potential for relocating the crossing should be assessed.

Where streams must be crossed the least damaging construction techniques should be employed, as described in subsequent sections of this handbook.

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2.4

Permanent Haul Road
Temporary Haul Road
Skid Road (or trail)
Bridge (water crossing)
Landing

Plans A, B, and C show three ways to place truck and skid roads on a cutting unit. The comments next to each plan indicate why Plan C is best.

Plan A layout: 2 bridges
4 landings
3 miles of haul road

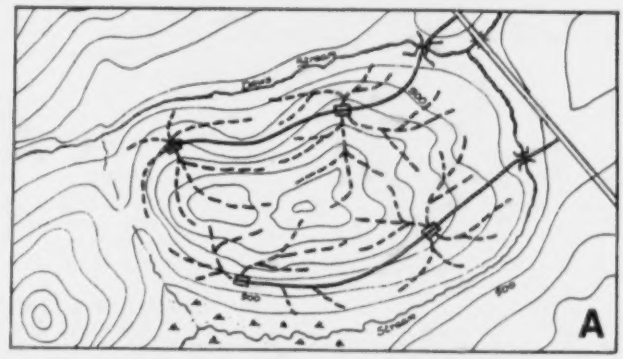
Comment: Road and bridge construction costs too high. Skid distance too short. Too much steep downhill skidding. Too many landings on too steep land. Two bridges are unnecessary.

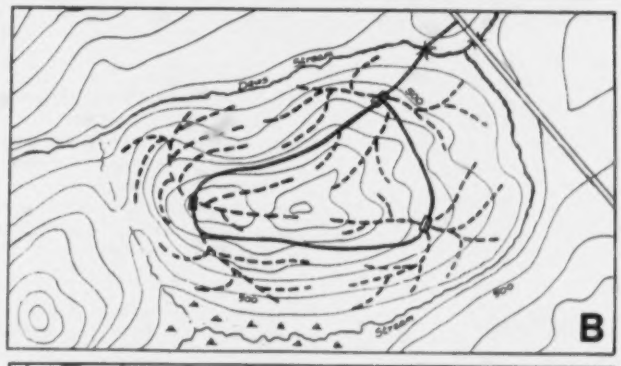
Plan B layout: 1 bridge
3 landings
3.5 miles of haul road

Comment: Loop road unnecessary. Skid distances too short. Erosion minimized up hill skidding.

Plan C layout: 1 bridge
2 landings
2 miles of haul road

Comment: Haul road follows high ground. Minimal road construction. Ideal skidding distances. Erosion minimized by uphill skidding. Least number of landings. Only one bridge required.





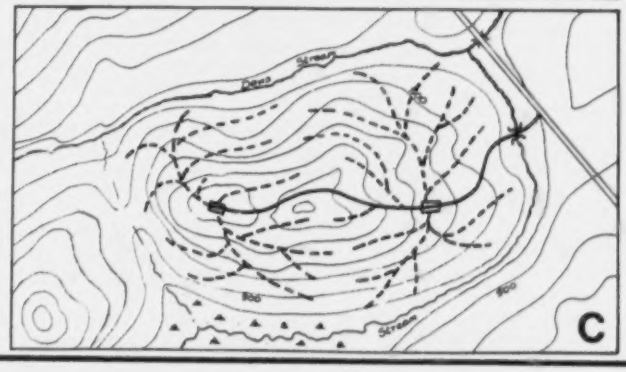


Figure 5 **How to select the best road layout: an example (Illustration adapted from the Maine Land Use Regulation Commission).**

Figure 6 **Approach to bridge in logging road. Note uniform grade of approach and perpendicular orientation of road and stream (Photo courtesy of USDA Forest Service).**

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2.5 Borrow Areas

Purposes

a) To limit channel disturbances and sediment production associated with gravel source development.

b) To protect salmonid and other fishery spawning sites.

Description

Borrow pits should not be located in waters of the United States (Figure 7). Excavation should not take place below the water table unless sediment basins are built to contain or catch the resulting sediment (USDA Forest Service 1979).

Figure 7 **This borrow area is located on a ridge, high above any waters which could otherwise be adversely affected by gravel mining through direct removal of fish spawning sites and indirectly by erosion, turbidity, and sedimentation (Photo by J.R. Hynson).**

Performance

Gravel mining directly from streams causes a multitude of impacts including destruction of fish spawning sites, turbidity, and sedimentation. With this BMP, these impacts would be eliminated or significantly reduced (USDI Federal Water Pollution Control Administration 1970).

Limitations

Economically, if a high demand and low supply of gravel existed, obtaining gravel could be difficult. Moreover, in the western states prohibitions on gravel mining could force use of talus (an accumulation of broken rocks at the base of a cliff) which in some areas serves as important wildlife habitat (Thomas 1979).

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2.6 Disposal Areas

Purposes

a) Prevent entry of dredged spoil into aquatic systems.

b) Avoid destruction of wetland habitats.

Description

Dredged spoil, waste, and/or other debris should not be deposited in aquatic or wetland habitats. Spoil should be deposited in upland areas and not in a location that it would be expected to enter waters of the United States. When spoil is placed, it should be compacted (BMP 5.7).

The final slope after disposal would be no steeper than 1 1/2:1. Where practical, the spoils should be located on an area with low productivity and where the risk of soil erosion and mass soil movement is minimal. All soils should be placed to allow drainage without water ponding (Washington Forest Practice Board 1976).

Performance

Sachet et al (1980) felt that in Washington, where regulations prohibit depositing any debris within the 25-year flood plain of high quality waters, few major water quality problems resulted from disposal areas. This was largely due to compliance with the regulation.

Limitations

The BMP would be limited by the availability of acceptable disposal sites.

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Restrictions on Use of Dry Hollows 2.7

Purpose

To avoid damaging natural drainage, creating erosion, or destroying habitat of semi-aquatic species.

Description

Dry hollows are streambeds or other low areas which are flooded only seasonally or intermittently throughout most years. Most are considered wetlands by FWS definition. They may be heavily wooded or unvegetated. Such areas provide prime habitat for a variety of semi-aquatic species which may burrow into bottoms and banks during dry periods. Due to the heavy concentrations of semi-aquatic species and the erosional tendencies, roads and skid trails should not be sited in these areas.

Performance

North Carolina recommends this BMP (North Carolina Division of Forest Resources 1979). No published reports address its efficacy in protecting fish or wildlife. Although usually having no standing water, these areas recycle nutrients very effectively, often have lush herbaceous growth valuable to wildlife, and may harbor large concentrations of dormant aquatic organisms and amphibians. In some regions they may also be important aquifer recharge areas.

Limitations

Legally, such areas may not be considered as waters of the United States and, therefore, not subject to regulations under dredge and fill guidelines. However, in view of their possible environmental values, dry hollows should be avoided whenever feasible.

References

* North Carolina Division of Forest Resources. 1979. Forest practice guidelines related to water qaulity. Dept. Nat. Res. and Comm. Devel. Raleigh. 36 p.

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3.0 Design

3.1 Minimum Design Standards

Purpose

To minimize the overall area of earth changes in waters of the United States.

Description

A minimum design standard should be used for stream and wetland crossings that does not involve excessive earth change operations but produces a road sufficient to carry the anticipated traffic load with reasonable safety (Washington Forest Practice Board 1976, USDA Forest Service 1973). Several parameters exist (Figure 8) which could be used to specify design standards for a BMP system. Common measurements include, but are not limited to road width (traveled way plus shoulders), subgrade width, and clearing limits.

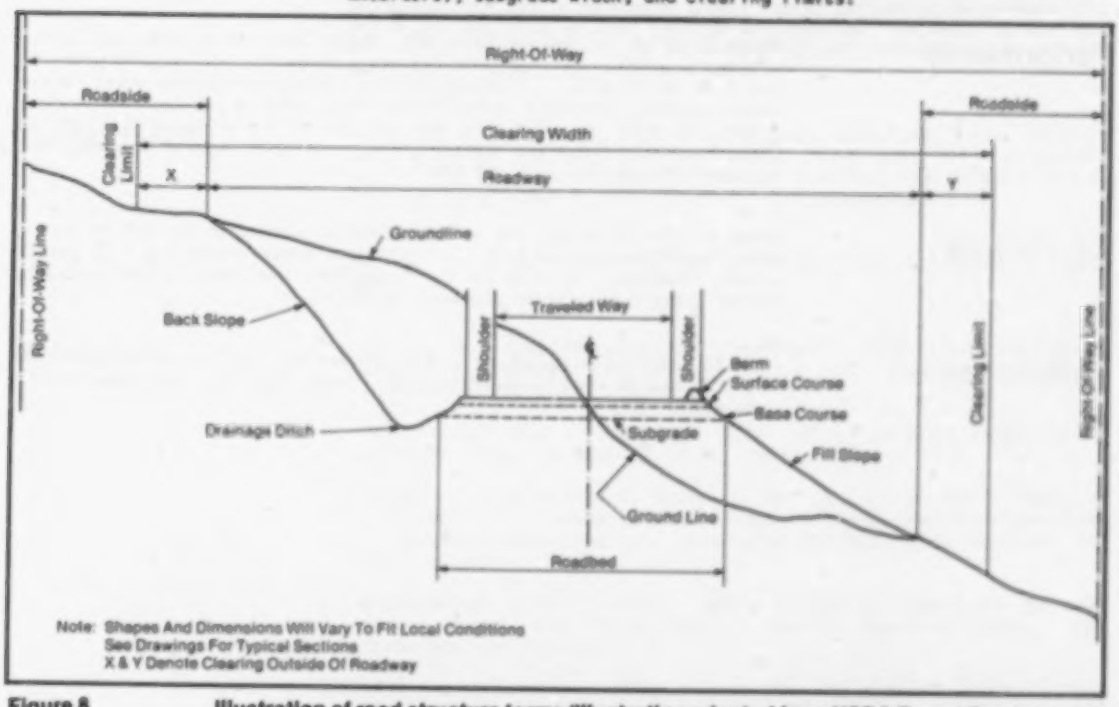

Figure 8 **Illustration of road structure terms (Illustration adapted from USDA Forest Service 1979).**

Road width. Minimum road width is commonly specified from 10 feet (Vaughn and Committee 1979) to 14 feet (USDA Soil Conservation Service 1977) for single lane haul and access roads. A common measurement for single lane roads is 12 feet (Hewlett et al. 1979, USDA Forest Service 1980). Curves and turnouts require additional width. Virginia recommends a minimum width of 16 feet for curves (Vaughn and Committee 1979), while the USDA Forest Service (1980) recommends 24 feet as the maximum turnout width in Colorado.

Road widths for double lane roads range from 20 feet (Vaughn and Committee 1979; USDA Soil Conservation Service 1977) to 22 feet (USDA Forest Service 1980). If trailers are to be used, an additional 4 feet is often recommended (Vaughn and Committee 1979, USDA Soil Conservation Service 1977).

Minimum Design Standards 3.1

The USDA Soil Conservation Service (1977) provides design standards for the width of the traveled way and width of the shoulders. The traveled way minimum width is 10 feet for single lane roads, and 15 feet for double lane roads, and 20 feet for two way traffic with trailers. Minimum shoulder width is 2 feet on each side of the tread width. SCS standards are provided at the state level through the agencies' "Technical Guide" and are revised periodically. Therefore, the reader should be advised to consult the latest revision for the appropriate state.

Subgrade width. The approach of setting maximum allowable subgrade width is used by the state of Washington (Washington Forest Practice Board 1976). Their regulations state that maximum subgrade width should not be more than 32 feet on the average for double lane roads and 20 feet for single lane roads. This standard is exclusive of ditches and any additional width necessary for safe operation on curves and turnouts.

Clearing limits. Vegetation should be cleared only to the minimum essential width required for construction and maintenance of the road (USDI Federal Water Pollution Control Administration 1970). In Colorado, the USDA Forest Service (1980) recommends normal limits as 2 feet beyond cut points and 4 feet from the shoulder in fills.

Performance

In most cases, this BMP would reduce the area of earth changes and thus erosion, sedimentation, and turbidity resulting from bare surfaces. Moreover, it would reduce loss of wildlife habitat, and constitute less of a barrier to wildlife movements. In an evaluation of Washington's standards, Sachet et al. (1980) recommended that those standards should be retained.

Limitations

Most of the publications which listed this BMP, described it as being equally adaptable to upland situations as to stream and wetland crossings. However, only the sites of stream and wetland crossings are within the scope of this report.

Minimum design standards should allow for the normal width of logging trucks, skidders, tractors, and farm machinery in the area of interest. Moreover, clearing limits that are too narrow could prevent sunlight from reaching the road surface, and thus significantly lengthen the time it takes for the road to dry after a storm. Such a delay could result in rutting of the road, accelerated erosion and increased sedimentation.

References

* Hewlett, J.D., W.P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia and USDA Forest Soil Conservation Service. Athens. 25 p.

* Sachet, J., S. Keller, A. McCoy, T. Orr, Jr., and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practice regulations in protecting water quality. Washington Dept. Ecol. Rept. No. DOE 80-7. Olympia. 76 p.

U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. California Region. San Francisco. 13 p.

* USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720-100. Washington, D.C. 461 p.

* USDA Forest Service. 1980. Geometric design. Forest Service Handbook Section 24. Region 2 Supplement 7. Denver, Colorado.

* USDA Forest Service. 1980. Road widths and turnouts. Section 24.22 of Transportation Engineering Handbook, FSH 7709.11. Region 2 Supplement No. 7. Denver, Colorado.

* USDA Soil Conservation Service. 1977. Access Road Technical Guide, Section IV, 560. Denver, Colorado.

* USDI Federal Water Pollution Control Administration. 1970. Industrial waste guide; logging practices. Northwest Region. Portland, Oregon. 40 p. + 37 figures.

* Vaughn, C.E. and Committee. 1979. Best management practices handbook; agriculture. Virginia State Water Control Board, Planning Bulletin 316. Richmond.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Department of Natural Resources, Division of Private Forestry Assistance and Regulations. Olympia. 54 p.

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Choice of Water Crossing Structure; Bridges 3.2

Purposes

a) Provide for fish passage.

b) Minimize discharge of fill in waters of the United States.

c) Protect waters from flow alterations.

Description

A properly located, designed, and prepared crossing structure (bridge, culvert, or ford) should be used at all water crossings. Sites should be designated, and all equipment should cross only at those sites, and none other.

Three general types of water crossing structures are commonly used: bridges, culverts with fill, and fords. Of these three, bridges offer the least amount of obstruction to fish passage, the least use of fill within the water limits, and usually the least amount of alteration to bottom topography (Figure 9). Bridges are necessary in selected, important cases. These cases include, but are not limited to:

1. Where the risk of erosion and sedimentation are high;
2. Along important fishery migration routes;
3. Where waters are regularly used for recreational boating; and
4. Where important riparian wildlife movement would be otherwise blocked.

One possible exception to this rule would be permitting the use of pipe arch culverts (BMP 3.6) over high value waters.

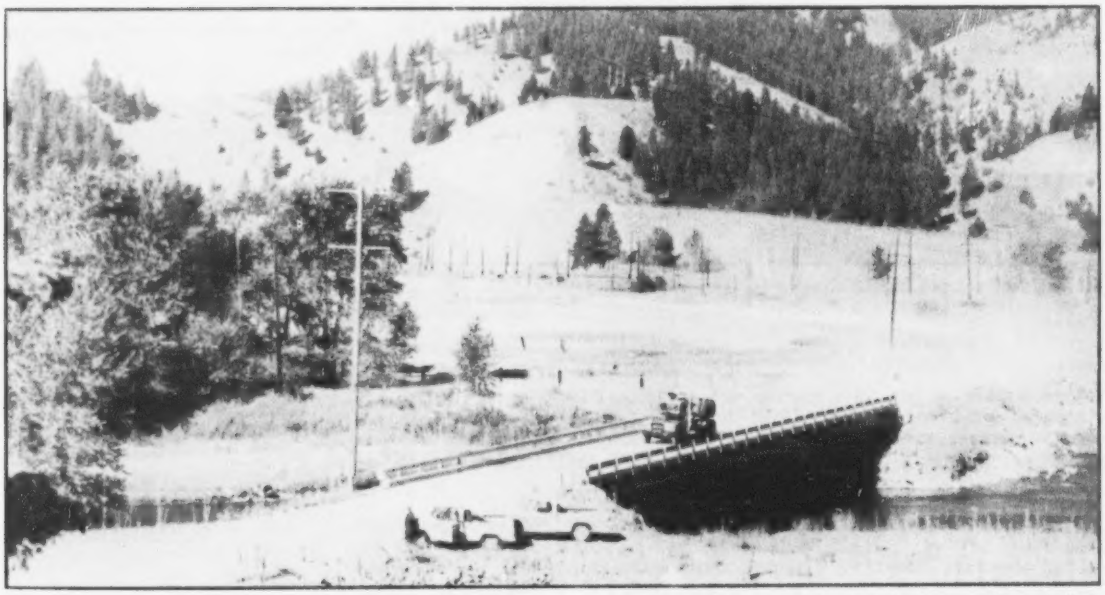

Figure 9 **Of the water crossing alternatives, bridges generally provide the best quality of fish passage, most reduce the possibility of fill failure, and provide for the most natural flow conditions. (Photo courtesy of USDA Forest Service).**

3.2

Performance

In addition to being recommended by several state and federal programs, this BMP is routinely advocated by fishery biologists (Evans and Johnston 1980; Yee and Roelofs 1980).

Limitations

Proper bridge design, as described in subsequent sections of this handbook should be employed. Otherwise, bridges could significantly increase erosion and sedimentation from washouts and other forms of structural failure. Moreover, improperly designed bridges would alter flow and circulation of the wetland.

In very selected cases, fords (BMP 3.16) could have significantly less impact than bridges. These instances include crossing intermittent streams with stable banks and beds only during periods of low water.

Permanent bridges are by far the most costly alternative water crossing structure. Temporary log stringer bridges, on the other hand, are often the most inexpensive water crossing structure.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM-7100-12. Washington, D.C. 63 p. + App. A-F.

Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd. Edition. USDA Forest Service, State and Private Forestry, Northeastern Area. Broomall, Pa. 43 p.

* Yee, C.S. and T.D. Roelofs. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America. 4. Planning forest roads to protect salmonid habitat. USDA Forest Service Gen. Tech. Rept. PNW-109. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. 26 p.

*cited in text

Log Stringer Bridge Designs 3.3

Purpose

To provide a low cost, environmentally acceptable stream crossing structure.

Description

For temporary bridges, or for semi-permanent structures on secondary forest or farm roads, a design based on the use of log stringers provides a relatively low cost alternative for small stream crossings (Figure 10). Although native tree species can be used for the stringers, materials should not be cut from the streambank. The tops of the stringers are slabbed off flat to supply a good running surface. Decking consists of 3 inch planks or poles laid solidly across the stringers. Running planks, 3 inches thick, are placed over the floor lengthwise and parallel to the stringers. Wheel guards are placed at the outer edges of the deck, and strips of asphalt paper can be placed between stringers and decking to shed water.

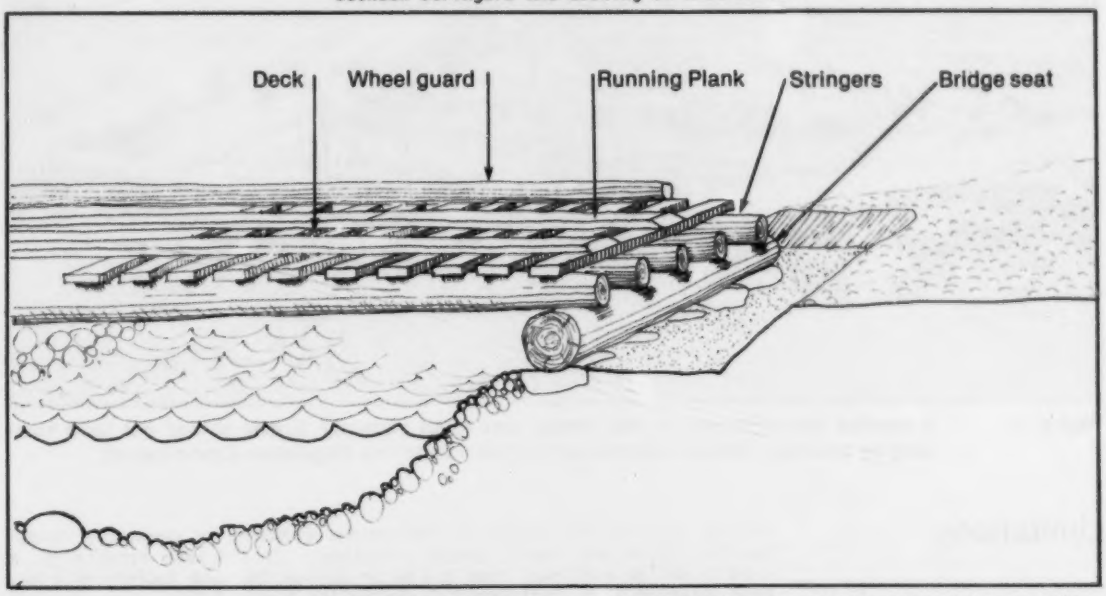

Figure 10 **How to construct a simple log bridge (Illustration adapted from the Maine Land Use Regulation Commission).**

The bridge seat should parallel the stream flow and be placed on firm material (Owen and Lyons 1980, Kent 1978) Gravel should not be used to surface the bridge, since it collects water and causes the support structures to rot (Kent 1978; Figure 11).

Performance

Where water values are important, the bridge has already been described as the most acceptable alternative (BMP 3.2). In the Northeast, Kochenderfer (1970) reported that properly designed stringer bridges easily supported 15 ton bulldozers and could carry loaded logging trucks for many years. The BMP is widely accepted in the Eastern U.S. In the Western U.S., a need has been recognized for more individual and site-specific bridge designs.

3.3

Figure 11 **A washed out log bridge — this bridge was sized correctly. Gravel should not have been used as a surface. (Photo courtesy of the Maine Land Use Regulation Commission).**

Limitations

Use of this design should be limited to secondary or temporary roads, and for relatively small stream crossings. In the west especially, a need to design each haul road and major stream crossing individually has been observed (U.S. Environmental Protection Agency 1975).

Since log bridges are made mostly or entirely from native materials, they could degrade and be used beyond the life of the logs. Such conditions would cause failure under a heavy load. Moreover, log bridges are subject to erosion and washout from high water, and thus should not be left in place during high water periods unless designed to pass expected flood flows. The structures should be removed following logging or when their intended use is complete.

References

Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd. Edition. USDA Forest Service, State and Private Forestry, Northeastern Area. Broomall, Pa. 43 p.

* Kent, B. 1978. Erosion control on logging roads. The Land Use Handbook, Section 6. Maine Dept. Cons., Land Use Reg. Comm. Augusta. 28 p.

* Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. USDA Forest Service Res. Paper NE-158. Northeastern Forest Exper. Stn., Upper Darby, Pa. 28 p.

* Owen, L.J. and T.M. Lyons. 1980. Logging roads and skid trails; a guide for soil protection and timber access. Indiana Dept. Nat. Res. Div. Forestry. Indianapolis. 21 p.

North Carolina Division of Natural Resources. 1979. Forest practices guidelines related to water quality. Dept. Nat. Res. and Comm. Development. Raleigh. 36 p.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

*cited in text

3.4 Elements of Permanent Bridge Designs

Purposes

a) Provide for expected flood flows.

b) Avoid debris blockage.

c) Prevent obstructions to flow.

Description

Permanent bridges should be designed to fit the site, rather than developed from a standardized design (U.S. Environmental Protection Agency 1975). In doing this, the following points should be considered:

1. Bridges should not constrict clearly defined channels. They should be designed to pass the 50-year (or other limits imposed by regulations) flood levels, or the road should be constructed to provide erosion protection from the 50-year (or other limits imposed by regulations) flood waters which exceed the water carrying capacity of the drainage structure (Washington Forest Practice Board 1976). The U.S. Environmental Protection Agency (1975) recommends a vertical clearance of at least 5 feet above the 50-year flood level and a lateral width of the 50-year flood if the bridge is designed to pass the water under it.

2. In order to prevent obstruction by debris during a flood event, horizontal clearance should be not less than 85 percent of the anticipated tree height (U.S. Environmental Protection Agency 1975).

3. Abutments should parallel stream flow and be imbedded in good foundation material (Owen and Lyons 1980).

4. If any of the bridge is within 10 vertical feet of the 50-year flood level, one end should be anchored or firmly tied (Washington Forest Practices Board 1976).

5. Where possible, support structures should be kept out of the streambed (Vaughn and Committee 1979, Thronson 1979; Figures 12 and 13).

6. The top width of the bridge should be adequate to prevent sloughing of the side slopes (Michigan Dept. Nat. Res. 1974).

7. Bridge support structures should be placed in such fashion as to permit unimpeded up and downstream transit of the floodplains by wildlife species.

8. For exceptionally wide floodplains, a series of bridges between leveed roadways would permit water passage during flood times and wildlife passage during periods of low water. This is preferable to a single long fill across the floodplain.

Performance

Those items used in the state of Washington have been evaluated as useful and implementable BMPs (Sachet et al. 1980). Items addressed by the U.S. Environmental Protection Agency (1975) resulted from detailed interagency consultation.

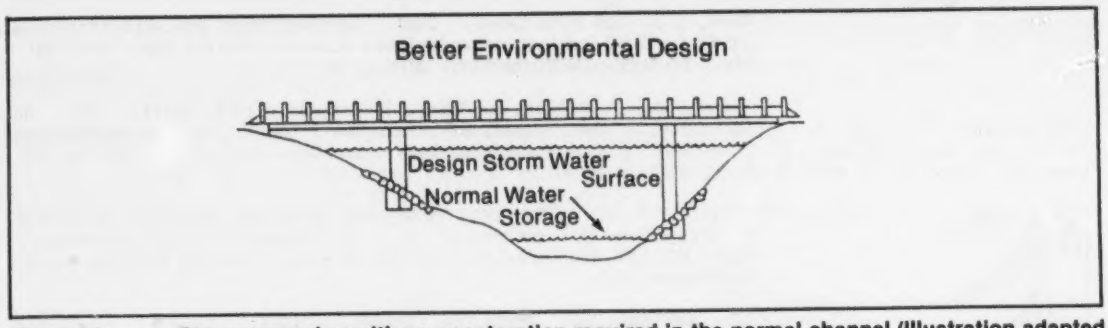

Figure 12 **Stream crossing with no construction required in the normal channel (Illustration adapted from Thronson 1979).**

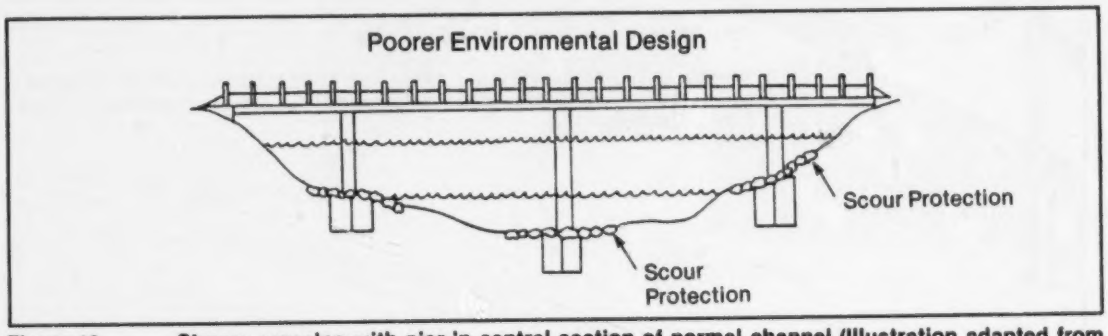

Figure 13 **Stream crossing with pier in central section of normal channel (Illustration adapted from Thronson 1979).**

The BMP would markedly reduce flow alterations during flood events, and thus generally benefit fish and wildlife. The BMP would also slightly decrease turbidity, shoreline erosion, and sedimentation and thus be somewhat beneficial to fish and wildlife. Standards for the size of the passage under the bridge would enhance the ability of wildlife to pass under the bridge during normal flow periods.

Limitations

For this BMP, most of the limitations result from specifications regarding horizontal clearance. In many instances, meeting both the specifications for flood level and for tree height would be impossible. Tree height criteria would be especially difficult to meet in some narrow canyons. In wide valleys, requiring a horizontal clearance the width of the 50-year flood could be prohibitively expensive.

References

* Michigan Department of Natural Resources. 1974. Rules and regulations concerning Inland Lakes and Stream Act. Hydrological Survey Division. Lansing.

* Owen, L.J. and T.M. Lyons. 1980. Logging roads and skid trails; a guide for soil protection and timber access. Indiana Dept. Nat. Res. Div. Forestry. Indianapolis. 21 p.

* Sachet, J., S. Keller, A. McCoy, T. Orr, Jr. and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practice regulations in protecting water quality. Washington Dept. Ecol. Rept. No. DOE 80-7. Olympia. 76 p.

* Thronson, R.E. 1979. Best management practices guidance, discharge of dredged or fill materials. U.S. Environmental Protection Agency. Publ. No. EPA 440/3-79-028. Office of Water Planning and Standards. Washington, D.C.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. of Private For. Assist. and Regs. Olympia. 54 p.

* Vaughn, L.E. and Committee. 1979. Best management practice handbook; agriculture. Virginia State Water Control Board, Planning Bulletin 316. Richmond.

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Criteria for Using Concrete Aprons Under Bridges 3.5

Purpose

To provide for fish passage.

Description

Concrete aprons should be avoided if at all possible (Figure 14). Proper stream crossing location (BMP 2.4), and avoiding the use of instream support devices (BMP 3.4) would do much to alleviate the need for this type of structure.

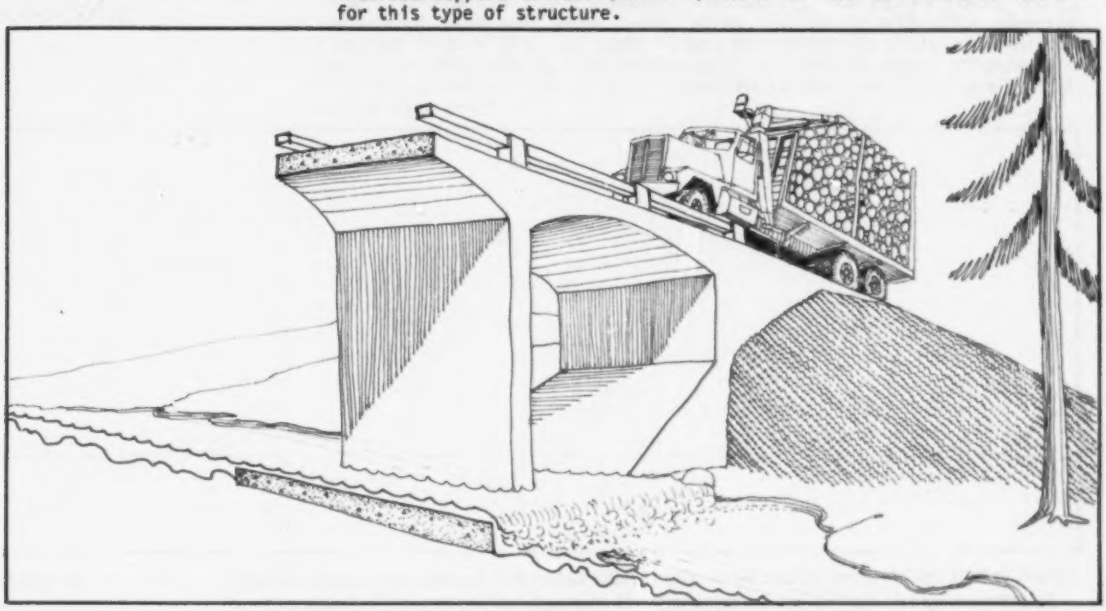

Figure 14 **Apron under bridge unsuitable for fish passage, flow too shallow over stream bottom. (Illustration adapted from Evans and Johnston 1980).**

If concrete aprons must be used the following provisions can be used to provide for fish passage.

1. Construct a weir or a check dam 20-30 ft below the concrete apron. Such a structure will create a pool, and thus increase depth at the site of the apron. This modification is especially useful if the stream gradient is rather steep.

2. Angle the concrete apron down towards the middle of the stream. In this manner, a low flow channel is created which provides for fish passage.

3. As a last resort, a fishway can be constructed.

Performance

Avoiding the use of concrete aprons altogether will alleviate problems. The other criteria would be at least partially successful.

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3.5

Limitations

The use of a weir or a check dam, if it significantly modifies flow or circulation, could require a dredge and fill permit. The fishway alternative is commonly extremely expensive.

References

Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-F.

Choice of Water Crossing Structure; 3.6 Culvert Types

Purposes

a) Provide for fish passage.

b) Minimize discharge of fill in waters of the United States.

Description

Three culvert types are commonly available: corrugated round metal, corrugated pipe-arch metal, and structural plate-arch with concrete footings (Figure 15). Of these three, the structural plate-arch culvert should be required on high value water or fishery areas (Figure 16). This BMP could be used as an alternative to the use of bridges on high water-value areas.

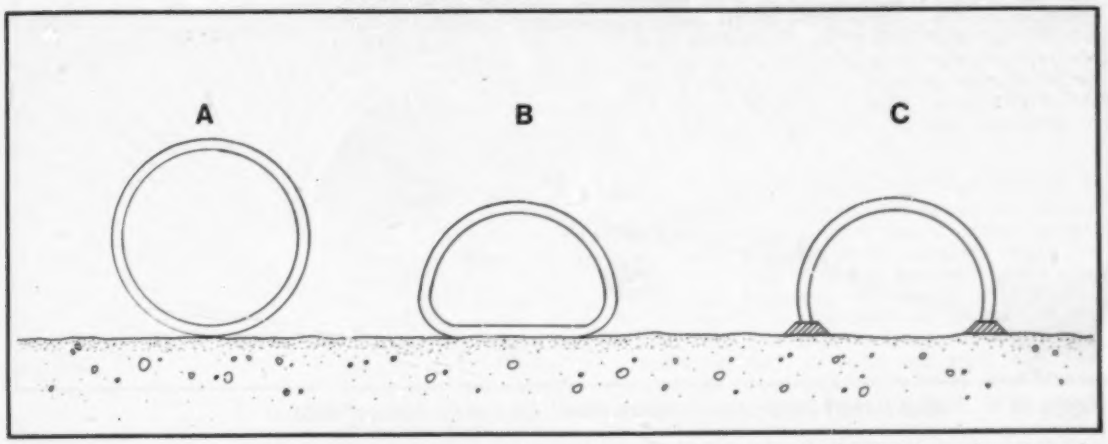

Figure 15 **Typical cross sections of the most commonly used metal culverts on forest roads. A—Corrugated round metal culvert, B—Corrugated pipe-arch metal culvert, C—Structural plate-arch with concrete footings (also available in semicircular cross section) (Illustration adapted from Yee and Roelofs 1980).**

Performance

Of the three alternatives, the structural plate arch culvert has at least two major assets: (1) it retains the original character and biological productivity of the streambed under the crossings, and (2) if properly sized it allows for the natural depths and flow velocities which are generally more suitable to providing for fish passage than those altered by man.

This BMP is accepted by the USDA Forest Service, the U.S. Environmental Protection Agency (1975), and the State of Washington (Washington Forest Practice Board 1976). It is widely recommended by fishery biologists (Evans and Johnston 1980, Yee and Roelofs 1980).

Limitations

From an engineering standpoint, the natural streambed and stream bank must consist of a fairly stable material, or else the structure will fail. Ecologically, the plate-arch culvert has a somewhat greater potential than a bridge to block passage of riparian animals and has less capacity than a bridge to handle large flow volumes. However, the plate-arch culvert is far superior to the round corrugated culvert for both wildlife passage and the ability to perform during floods.

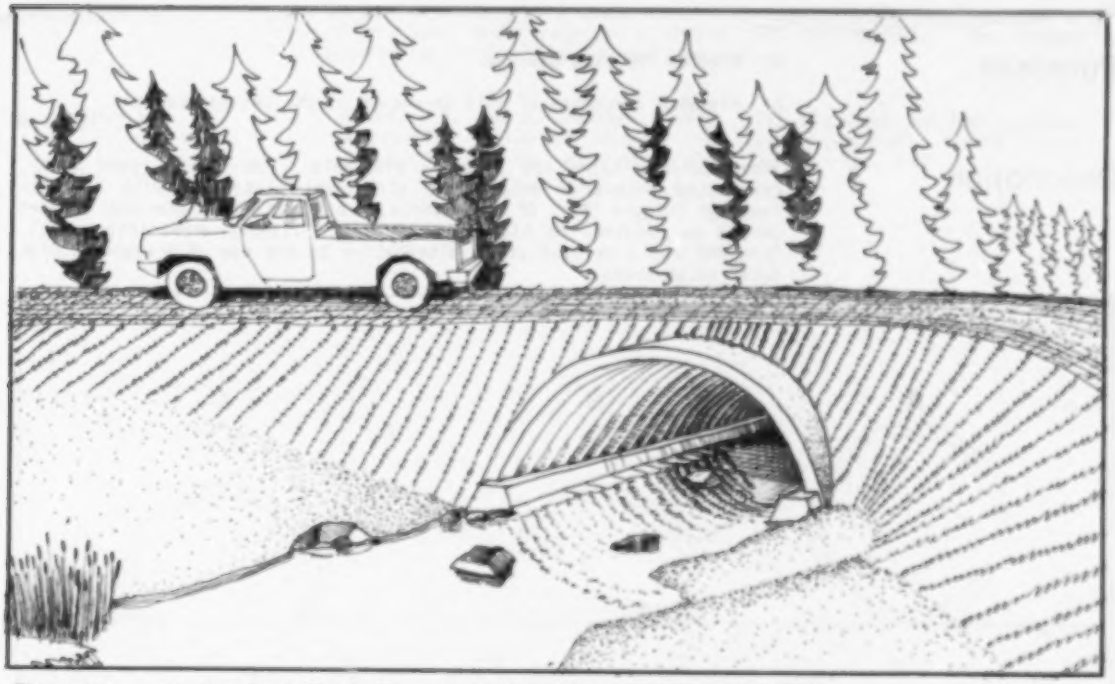

Figure 16 **Arch culvert (Illustration adapted from Evans and Johnston 1980).**

The plate arch culvert is significantly less expensive than most bridges, but is more expensive than other culvert types and fords. The least expensive of the culverts is the round corrugated metal culvert.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-F.

* U.S. Environmental Protection Agency. 1975. Logging roads and the protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. Priv. For. Assist. and Regs. Olympia. 54 p.

* Yee, C.S. and T.D. Roelofs. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America. 4. Planning forest roads to protect salmonid habitat. USDA Forest Service Gen. Tech. Rept. PNW-109. Pacific Northwest Forest and Range Exper. Stn. Portland, Oregon. 26 p.

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Choice of Water Crossing Structure; 3.7 Single vs. Multiple Culverts

Purposes

a) Prevent debris blockage.

b) Provide for fish passage.

c) Provide for wildlife passage.

Description

In many instances, either one large single culvert, or several smaller culverts can be used to channel stream flow under a road/water crossing. Site specific variables determine the optimum choice.

Single culverts. One large culvert is generally the preferred approach for most stream crossings (Evans and Johnston 1980), but is not preferred under conditions of high variability of stream flow. It is also not preferred on wetland crossings where the wetland is too wide to span with one large culvert. Such a design aids in reducing the amount of debris blockage, provides for better wildlife passage, and permits flow to be channelled through at reduced velocities. Slower velocity of flows enables fish passage.

Multiple culverts. Multiple culverts can provide for fish passage on streams with a wide range of difference between peak flows and minimum flows. In these instances, one single culvert would either create excessive velocities at high flows or not provide adequate depth for passage at low flows. However, a system of having one small culvert at or slightly below the level of the streambed, and several other larger culverts somewhat above it can easily be designed to concentrate the flow during low water periods and provide for flood flows (Yee and Roelofs 1980; Figure 17). Where multiple culverts are used for stream crossings in Washington, regulations state that one culvert should be at least 6 inches below the level of the other culverts (Washington Forest Practice Board 1976).

Multiple culverts can also be considered in wide wetlands that cannot be spanned completely with a single culvert (Thronson 1979). In these situations, a single culvert would serve to channelize the flow, and perhaps either drain or inundate areas to the sides of the culvert, depending upon the size of the culvert and the depth to which it is placed. Multiple culverts, on the other hand, would better provide for the more dispersed flow characteristic of a wetland.

Performance

When the correct choice of culvert type is made on a site-specific basis, fish passage is best provided for at a wide range of flow conditions, flood flows are not blocked, wildlife movement is not encumbered and wetlands are not channelized. The choice between single or multiple culverts for fishways is accepted by the USDA Forest Service and most fishery biologists, while wetland ecologists generally recognize the need not to channelize wetland flow.

Limitations

In some instances, this decision should only be made after detailed analysis. If a stream is involved, the road planner needs to determine: (1) to what degree is fish passage possible at low and high water conditions, and whether or not it is a significant concern, (2) how important is riparian animal movement in this site-specific instance, and (3) to what degree is culvert blockage from debris a problem. For wetlands, the width is of prime concern, as is the number of natural drainageways existing along the wetland crossing and the degree to which flow occurs in areas other than the natural drainageways.

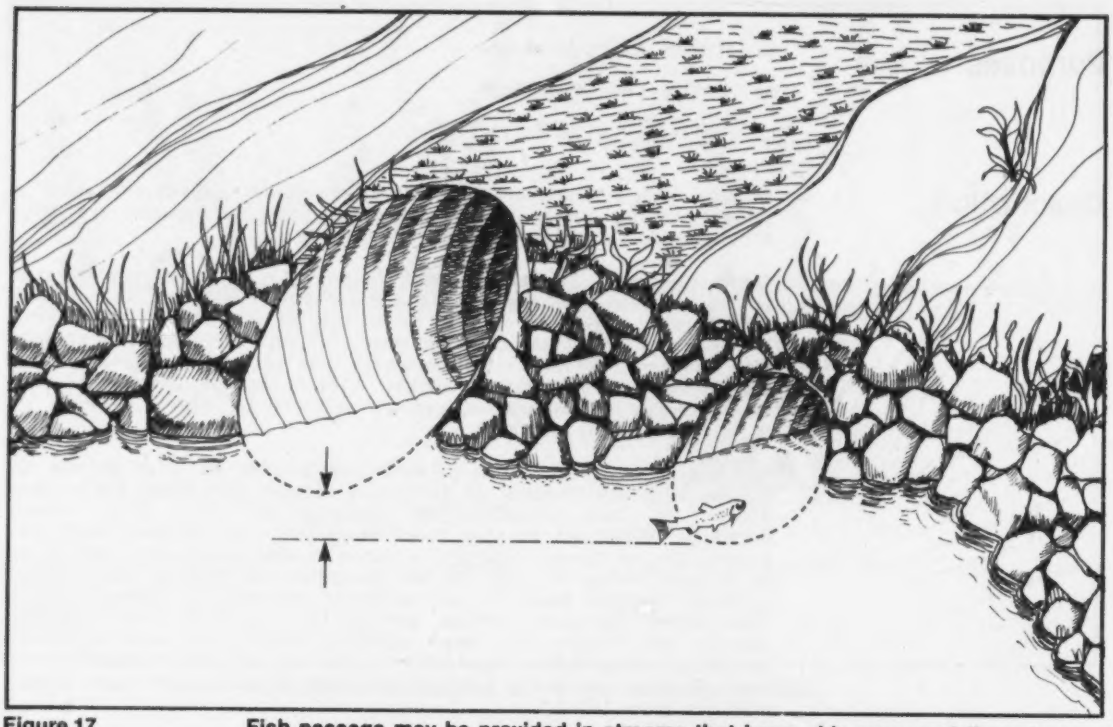

Figure 17 **Fish passage may be provided in streams that have wide ranges of flows by providing multiple culverts (illustration adapted from Yee and Roelofs 1980).**

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-F.

* Thronson, R.E. 1979. Best management practices guidance, discharge of dredged or fill materials. U.S. Environmental Protection Agency Publ. No. EPA 440/3-79-028. Office of Water Planning and Standards. Washington, D.C.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. Priv. For. Assist. and Regs. Olympia. 54 p.

* Yee, C.S. and T.D. Roelofs. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America. 4. Planning forest roads to protect salmonid habitat. USDA Forest Service Gen. Tech. Rept. PNW-109. Pacific Northwest Forest and Range Exper. Stn., Portland, Oregon. 26 p.

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Baffles in Culverts 3.8

Purpose

To reduce flow velocities in culverts and enhance fish passage.

Description

Baffles are long, rectangular blocks placed in culverts at angles to slow water velocities to the point where fish passage is possible (Figure 18; Evans and Johnston 1980). Such velocities are 4 feet/second for trout and 6 feet/second for salmon.

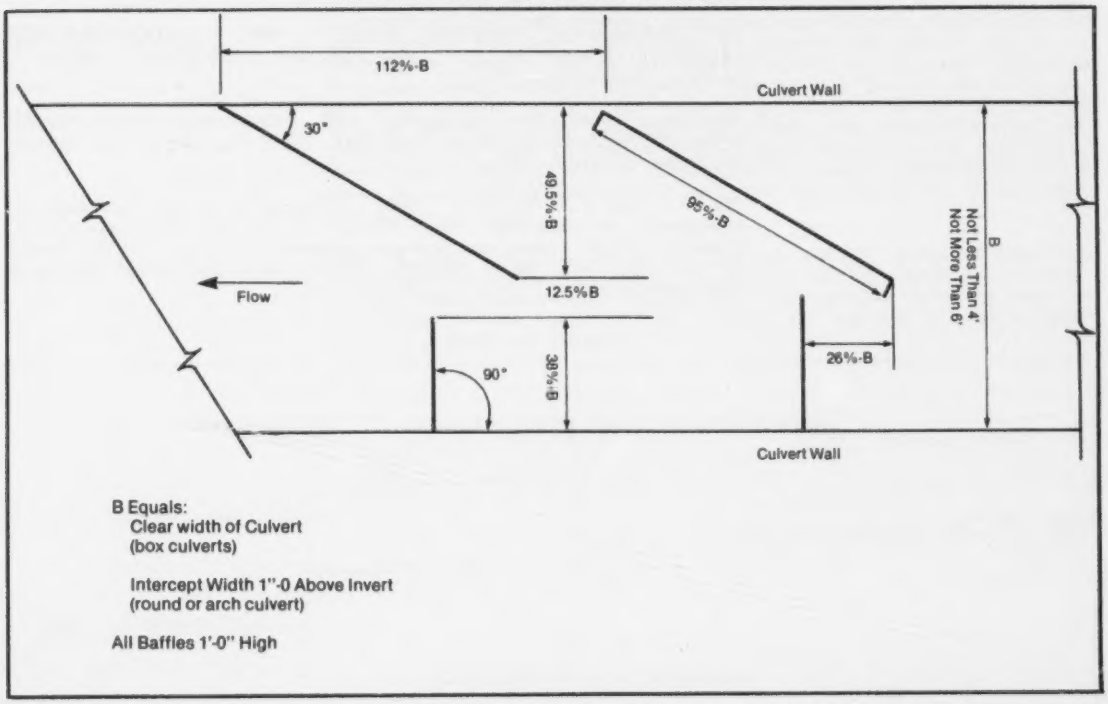

Figure 18 **Culvert baffles (Illustration adapted from Evans and Johnston 1980).**

Performance

Although baffles are no substitute for proper sizing and angling of culverts for fish passage, they do provide benefits when the proper culvert angle cannot be designed into the stream crossing structure (Evans and Johnston 1980). The efficacy of baffles has been variable, and depends greatly on local hydrological conditions. They are most effective when flows barely overtop them (U.S. Environmental Protection Agency 1975). They are suggested by the Forest Service (Evans and Johnston 1980), EPA (USDI Federal Water Pollution Control Administration 1970), and the State of Washington (Washington Forest Practice Board 1976).

Limitations

Baffles should be installed only if the design angle of the culvert must be greater than 1/2 percent, (Washington Forest Practice Board 1976) or if design velocities for the structure would exceed that acceptable for fish passage. Cost and the difficulty of maintaining them regularly are the primary drawbacks of baffles.

3.8

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM-7100-12. Washington, D.C. 67 p. + App. A-F.

* USDI Federal Water Pollution Control Administration. 1970. Industrial waste guide; logging practices. Northwest Region. Portland, Oregon. 40 p. + 37 figures.

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* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Wash. Dept. Nat. Res., Div. Priv. For. Assist. and Regs. Olympia. 54 p.

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*cited in text

Sizing and Angling Culverts 3.9

Purposes

a) To provide for acceptable water depths and velocities to permit fish to negotiate culverts.

b) To prevent obstruction of flow and culvert failure.

c) Provide for adequate drainage during flood flows.

Description

Several inter-related concerns should be examined when determining the most appropriate sizes and angles of culverts for use in stream and wetland crossings. The culvert should be sufficiently small to allow for water depths adequate to permit fish passage through the culverts, but large enough to pass the water at acceptable velocities for fish passage and to allow for expected flood flows. The angle of the culvert should be such that acceptable fish passage velocities are maintained. Where fish passage is not of concern, culvert angle should be such that water velocities are adequate to maintain the culvert free of sediment and debris.

Fish Passage. Culvert diameter and angle of culvert placement should be such that fish can pass through the culvert during migration and movement periods (Figure 19). The two most important variables to consider are depth of the water in the culvert and maximum allowable water velocity through the culvert.

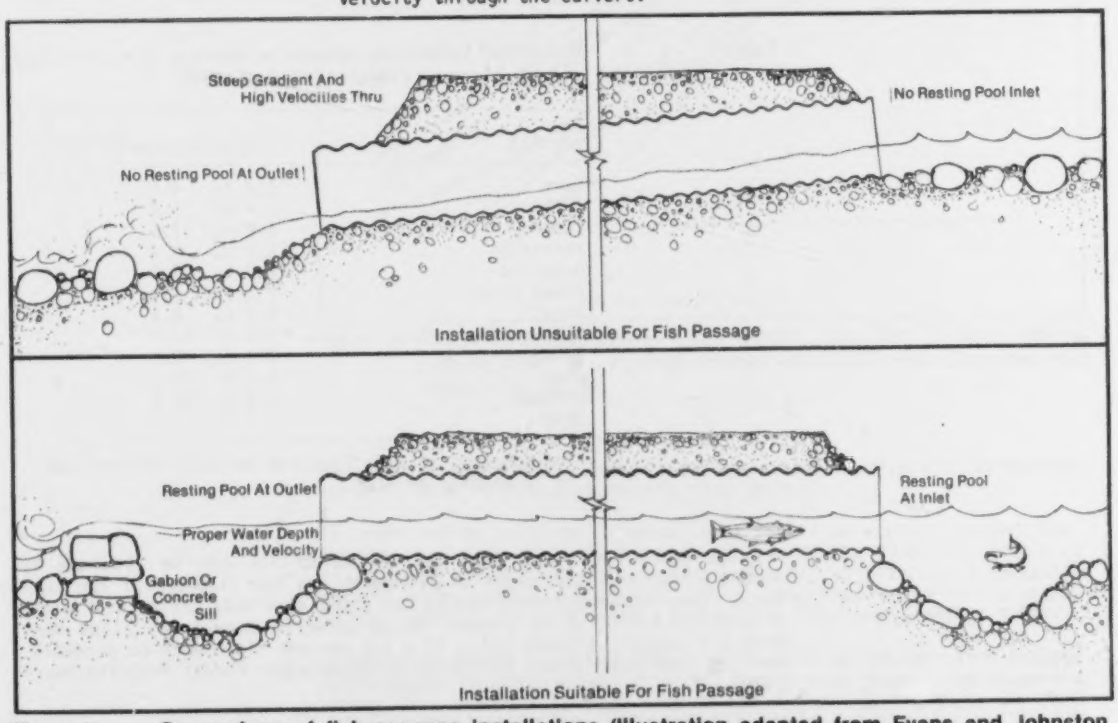

Figure 19 **Comparison of fish passage installations (illustration adapted from Evans and Johnston 1980).**

Evans and Johnston (1980) reported a minimum depth of 6 inches is required to allow passage of trout, while a minimum depth of 1 foot is required to permit passage of the anadromous salmon and steelhead of the Pacific Coast. Although few minimum depth criteria exist for other species, the depth has to be adequate for the fish to be completely immersed and not scrape bottom.

A good deal of work has been done to determine the most appropriate maximum design velocities for various fish. While most fish have three speeds of swimming (cruising, sustained, and darting), the sustained speed has been determined as the most appropriate variable for culverts of the length common to forest and farm roads (less than 100 ft.) (Watts 1977, Bell 1973). If culverts must be greater than 100 ft. long, cruising speed should be used.

Researchers have found that sustained swimming speeds vary with both the species and the size of fish. Watts (1977) and Bell (1973) listed the sustained speeds of a variety of normal sized adult fish (Table 7). Jones et al. (1974) determined the relationship between fish length and species with the ability to negotiate various water velocities during a specific time (Figure 20). The design velocity should be based upon the slowest appropriate swimming speed of the species and size of fish in the waters of concern.

Table 7. **Sustained swimming speeds of average size adult fish of several species (Watt 1977, Bell 1973).**

Species	Sustained speed* (fps)
Carp	1.2 to 4.0
Suckers	1.4 to 5.2
Lamprey	1.0 to 3.0
Whitefish	1.3 to 4.4
Grayling	2.5 to 7.0
Brown trout	2.2 to 6.2
Trout	2.0 to 6.4
Steelhead	4.6 to 13.7
Sockeye	3.2 to 10.2
Coho	3.4 to 10.6
Chinook	3.4 to 10.8
Shad	2.4 to 7.3

*The speed at which a fish can maintain for periods of 10 minutes or less.

Minimum depths and less than maximum velocities can be obtained by manipulating both the angle of placement and the diameter of the culvert. Open bottom culverts should not slope more than the natural angle of the streambed, while closed bottom culverts should not slope more than 1/2 percent (Figure 19). If a 1/2 percent slope must be exceeded, baffles (BMP 3.8) should be installed (Washington Forest Practice Board 1976).

Absolute minimum culvert diameters can be set to facilitate fish passage. In Washington, these are stated as 24 inches for anadromous fish streams and 18 inches for resident game fish (trout) streams (Washington Forest Practice Board 1976).

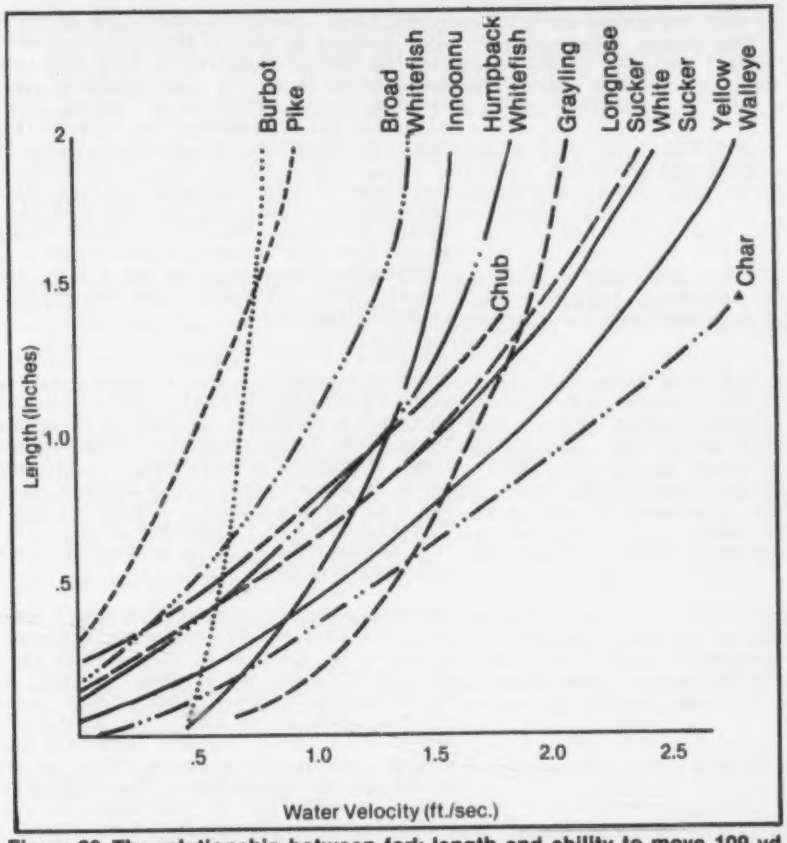

Figure 20 The relationship between fork length and ability to move 109 yd. (100 m) in 10 min. against various water velocities (Adapted from Jones *et al.* 1974).

However, it would still probably be necessary to calculate appropriate culvert installations on a case-by-case basis.

In order to do this, hydrological data should be used to predict low, average, and peak flows of the stream in question. Flows are then used to estimate velocities and depths of flow for various alternative culvert sizes, angles, and types. This estimation can be easily accomplished using a series of graphs prepared by Evans and Johnston (1980).

In the USDA Forest Service, common policy does not dictate fish passage requirements (maximum velocity) be met during peak flows. The reasoning behind this practice is that fish do not migrate during these periods. However, the installation should function during all normal periods of fish migration.

Flood flows. Culverts should be of sufficient size to prevent water from backing up behind the structures during expected storm events and causing excessive damage to both riparian ecosystems and to the structures themselves. This is generally accomplished through the use of a combination of criteria, including; (a) an absolute minimum culvert size, and (b) determining what culvert size is most appropriate in site-specific situations through knowledge of flows during flood events.

A common absolute minimum culvert size is 12 inches in diameter (Washington Forest Practice Board 1976). The most often cited flood levels are either the 25-year storm (Hewlett et al. 1979; USDI Federal Water Pollution Control Administration 1970), or the 50-year storm (Washington Forest Practice Board 1976; Evans and Johnston 1980; Yee and Roelofs 1980). The more often recommended, and more prudent alternative is the 50-year storm.

The use of higher frequency storm events (10 or 5-year) as a basis for design discharge has been a common practice in the past. However, these storm events have a fairly high probability of being exceeded any given year with a resultant increase in flood heights behind the roadfill. By translating flood frequency standards into probability measures, the level of risk is more evident. A five-year storm is actually one that has a 20 percent chance of occurring in any given year, a 10-year storm has a 10 percent chance, a 25-year storm has a 40 percent chance and a 50-year storm has a 2 percent chance. By designing for lower probability storms (50-year), it is possible to lower the chance of excessive backwater flooding.

Operationally, the road planner would need hydrological information for the area involved to determine expected discharges in volume/second units for the storm event indicated by the BMP. Where specific data are not available for the streams involved, empirical storm discharges can be developed. The United States Geological Survey has developed regional formulas in some areas of the country. These formulas utilize gauged data for a region's watershed and can be applied to ungauged streams, usually of 5 square miles or greater, to develop the appropriate design discharges. The USGS office in the state in question should be contacted for assistance in the use of these formulas where available, or in developing storm discharges for smaller watersheds or when no regional formulas have been developed. The local office of the Soil Conservation Service can also be contacted for storm discharge assistance. SCS has a number of empirical methods available for small watershed flood flow determination.

Sediment/obstruction cleaning. Where fish resources are not present, culverts can be angled to permit sufficient water velocities within the culvert which prevent sediment deposition. Generally, a flow greater than 2.5 ft./sec. will accomplish this. However, the flow should not exceed 8 ft./sec. (Haussman and Pruett 1978). This can generally be accomplished by placing culverts on a 2-4 percent grade in those situations where streams are small and the flow is naturally slow.

Performance

Fish passage. Appropriate sizing of culverts for fish passage has been a technique widely accepted by fisheries biologists for at least 10 years as evidenced by the discussion in the Description Section. In a recent review of Washington's forest practice regulations, Sachet et al. (1980) did not feel that changes were warranted. The technique is widely cited in BMP guidance documents (U.S. Environmental Protection Agency 1975; Thronson 1979).

Flood flows. Discharges for various classes of storm events can commonly be predicted fairly accurately, and crossings with appropriately sized openings will pass sufficient volumes of water. The most common cause of structure failure is underestimating the size of the storm event which can be expected during the life of the structure.

Sediment/obstruction cleaning. If such velocities are maintained, materials smaller than medium gravel will not settle in the culvert (Evans and Johnston 1980). Moreover, materials larger than large pebbles will not be eroded from the culvert outfall.

Limitations

One predominant limitation is that the objectives of provision for fish passage, insurance of the passage of flood flow, and prevention of sediment clogging often conflict. Therefore, at times additional design features must be added or compromises made.

For example, on streams that have a very wide fluctuation of flows, a design of adequate size to permit passage of flood flows might result in water depths insufficient to provide for fish passage during low water periods. In these instances, other design features, such as multiple culverts (BMP 3.7), or low flow channels (BMP 3.11) may be needed to meet resource objectives. In other cases, flows sufficiently slow to permit fish passage might conflict with the goal of preventing the culvert from clogging. In this instance, design priority should be given to fish passage design criteria, and culvert clogging prevented through adequate maintenance (BMP 6.2).

A second limitation is the need for technical expertise to implement this BMP. Required hydrological information includes expected volumes and velocities for the range of stream flows. Biological information required includes fish species present, and the movement patterns of the species involved, so that determination of the size classes expected to negotiate the culvert is possible.

The most appropriate flood event upon which to design culvert size will depend upon the following variables:

1. Expected longevity of the roads in the state or region of concern;
2. Variability in rainfall levels from year to year; and
3. Topography, especially width of the flood plain.

In all cases, culvert outflows should be adequately protected to prevent erosion of the streambed.

References

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* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-F.

* Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd. Edition. USDA Forest Service, State and Private Forestry. Broomall, PA. 43 p.

* Hewlett, J.D., W.P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia and USDA Soil Conservation Service. Athens. 25 p.

* Jones, D.R., J.W. Kiceniuk, and O.S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the MacKenzie River. J. Fish. Res. Board Can. 31:1641-1647.

* Sachet, J., S. Keller, A. McCoydd, T. Orr, Jr., and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practice regulations in protecting water quality. Washington Dept. Ecol. Rept. No. DOE 80-7. Olympia. 76 p.

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* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. of Private Forestry Assist. and Regs. Olympia. 54 p.

* Watts, F. 1977. Culvert fishways., 29 p., IN: Session 51; Annual meeting of the Transportation Research Board, Washington, D.C. University of Idaho, Moscow.

* Yee, C.S. and T.D. Roelofs. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America. 4. Planning forest roads to protect salmonid habitat. USDA Forest Service Gen. Tech. Rept. PNW-109. Pacific Northwest Forest and Range Exper. Stn., Portland, Oregon. 26 p.

*cited in text

Smoothed Bottom vs. Corrugated Metal Culverts 3.10

Purpose

To reduce velocity of flow through culvert and thus provide for fish passage.

Description

In most situations, corrugated metal culverts are preferred over smooth-bottomed culverts, since the corrugations provide for water velocities within the culvert which are slower and thus more amenable to fish passage. Smooth-bottomed culverts should only be used if depths greater than 1 foot are expected and low water velocities (less than 4 ft/sec) are present (Evans and Johnston 1980).

Performance

The irregularities in the surface of the corrugated culvert reduce the velocity of water traveling through the culvert, thus acting somewhat like baffles.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-

*cited in text

3.11 Low Flow Channels in Box Culverts

Purpose

To facilitate fish passage through box culverts during periods of low water.

Description

Box culverts should be equipped with a low flow channel which facilitates fish passage during low water periods (Vaughn and Committee 1979). Low flow channels can be incorporated in one of two ways. First, the bottom of the culvert can be sloped from both sides into the middle, creating a bottom structure in the shape of a V. Second, the bottom of the culvert can contain a groove of sufficient depth and size to provide for fish passage.

Performance

Low flow channels consolidate the water so that it is of sufficient depth to permit fish passage.

Limitations

These structures often have to be cleaned periodically as they fill with sediment.

References

* Vaughn, C.E. and Committee. 1979. Best management practices handbook; agriculture. Virginia State Water Control Board, Planning Bulletin 316. Richmond.

*cited in text

Resting Pools 3.12

Purpose

To enable fish passage through culverts.

Description

Resting pools are instream structures which provide fish an opportunity to gather strength before, during, and after negotiating a culvert that has relatively high water velocities. They are created by excavating the streambed and/or securely anchoring large diameter logs or gabions immediately downstream of a culvert (Figure 21). The pool should be no more than 3 feet deep but it should have a minimum depth of 6 inches for trout and 1 foot for salmon, and should be at least 12 feet long (Evans and Johnston 1980). It should be no wider than 5 times the original channel width. The logs for the check dam should be placed to impound water in such a manner that the drop between the culvert and the pool, and between the pool and the stream is passable by fish at all seasons. This BMP is especially recommended for culverts longer than 50 feet, and culverts having a high velocity of flow.

Performance

The importance of this BMP probably ranges from major in many rapid-flow sections of streams to minor in moderate-flow sections with many natural pools. It is recommended as a forest road BMP by EPA (USDI Federal Water Pollution Control Administration 1970) and the USDA Forest Service (Evans and Johnston 1980). They have been widely recommended in fishery management handbooks (Calhoun 1966; White and Brynildson 1967).

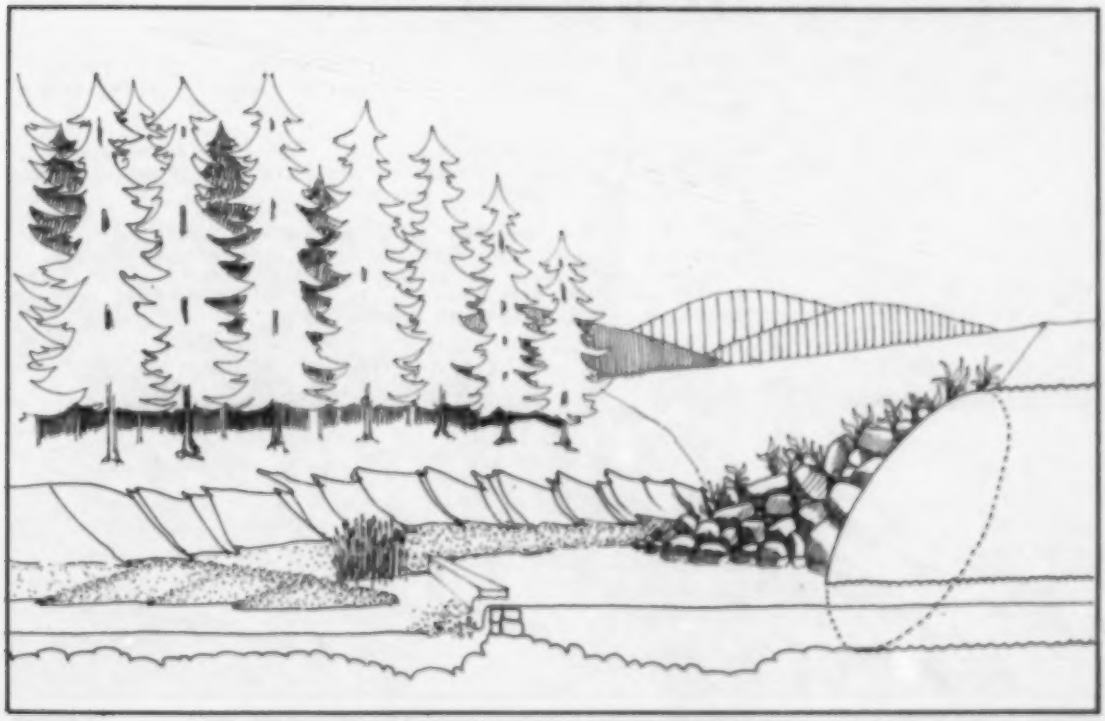

Figure 21 **Improved fish passage and resting pool created by use of gabions and a weir (Illustration adapted from Evans and Johnston 1980).**

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3.12

Limitations

In rapid-flow situations where they are most useful to fisheries, pools may be difficult and costly to maintain over the long term. Resting pools are generally impractical to construct where the streambed is bedrock or the shoreline so highly erodible that it is difficult to permanently secure any check-dam.

In some cases, the use of dams below culverts may cause excessive erosion to the streambank and fill material upstream from the check dam. Therefore, such devices should be installed only in those instances where the streambank is stable enough to support the additional erosion potential. In some situations, a cut into the streambank might be required.

In some situations, the check dam might constitute altering flow or circulation patterns, and thus require a dredge and fill permit. The long term effectiveness of a resting pool will be limited unless pools are checked and repaired after each year's flood flows.

References

* Calhoun, A. 1966. Habitat protection and improvement. In: Inland Fisheries Management. A. Calhoun (ed.). Calif. Dept. of Fish and Game, Sacramento.

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service, EM 7100-12. Washington, D.C. 63 p. + App. A-F.

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* White, R.J. and O.M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Wisconsin Dept. of Nat. Resources Tech. Bull. No. 39. Madison, Wisconsin.

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Drainage for Water Crossing Approaches 3.13

Purpose

Prevent roadfill from entering waters or wetlands, and thus reduce sediment contamination of aquatic ecosystems.

Description

This BMP involves providing for surface drainage for the roadbed on water crossing approaches. Water on the roadway should be diverted to the forest floor before reaching the water course. The forest floor would then serve as a filter for the sediment.

One method for accomplishing this would be the use of ditch relief or open top box culverts on downgrade approaches to the stream (Haussman and Pruett 1978; Figure 22). Another alternative would be the use of drainage dips on critical stream crossing approaches (Figure 23). A third alternative consists simply of breaking the grade of the road and dispersing water from that point (Kelly and Committee no date).

Figure 22 Open top box culvert properly installed in road (Photo courtesy of the USDA Forest Service).

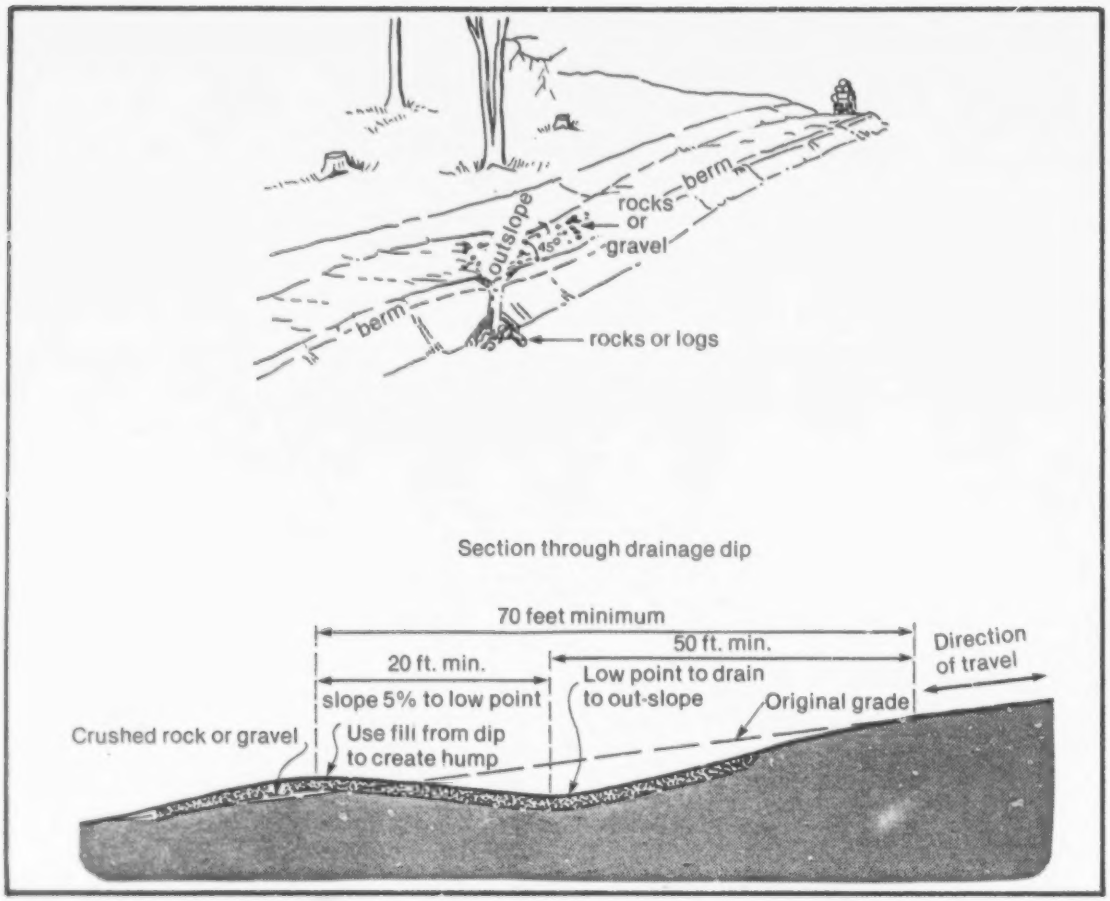

Figure 23 **Typical drainage dip installation (Illustrations adapted from Indiana Division of Forestry and Maine Land Use Regulation Commission).**

Performance

The use of all three drainage practices on the roadway surface has been extensively tested and widely accepted in the eastern United States (Haussman and Pruett 1978). They were recommended for the Pacific Northwest in principle by the Environmental Protection Agency (USDI Federal Water Pollution Control Administration 1970). The BMP benefits aquatic ecosystems by reducing sedimentation and stream turbidity at the crossing site.

Limitations

Adequate vegetative cover must be present between the drainage outlet and the water course to effectively filter sediment. If this does not exist, a sump hole or settling basin may be necessary. The settling basin would result in destroying a small amount of riparian vegetation. All types of basins would require periodic maintenance and cleanout.

Drainage for Water Crossing Approaches 3.13

Most authors recommend drainage structures for upland sites as well as approaches to water crossings. However, only the sites of water crossings are within the scope of this report.

References

* Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd. Edition. USDA Forest Service, State and Private Forestry. Northeastern Area. Broomall, Pa. 43 p.

* Keily, A.W. and Committee. n.d. Silviculture water quality management plan. West Va. Dept. Nat. Res., 208 Silvicultural Tech. Action Comm. Charleston. 50 p. + 5 Exhibits.

* USDI Federal Water Pollution Control Administration. 1970. Industrial waste guide; logging practices. Northwest Region, Portland, Oregon. 40 p. + 37 figures.

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*cited in text

3.14 Drainage Along Wetland Crossings

Purpose

To protect the ecological integrity of wetlands which cannot be avoided by the road alignment and to maintain road stability.

Description

Design and construct wetland crossings to maintain the natural surface and subsurface drainage. This can be accomplished through adequate sizing and spacing of water crossing structures, proper choice of the type of crossing structure, and installation of drainage structures at a depth adequate to pass subsurface flow. Bridges, culverts, and other structures should not perceptibly diminish or increase the duration, direction, or magnitude of minimum, peak or mean flow of water on either side of the structure.

Performance

Compliance with this BMP will insure that the value of wetlands for fish and wildlife will not be adversely affected by hydrologic impacts. It is recommended by the USDI Bureau of Land Management (1979).

Limitations

Costs of maintaining the natural drainage may be great if large expanses of wetland are involved. Drainage patterns and magnitudes at other seasons may not be apparent from a single site visit. Roads may require more frequent maintenance. This BMP does not protect wetlands from sediment impacts of road construction.

References

Schuldiner, P.W., D.F. Cope, and R.B. Newton. 1979. Ecological effects of highway fills on wetlands. Appendix A. Case Studies Supplement 7. Blocked drainage in peat and other soils with low hydraulic conductivity: Northeast Minnesota.

Stoeckeler, J.H. 1965. Drainage along swamp forest roads: Lessons from Northern Europe. J. of Forestry 63(10):772.

Stoeckeler, J.H. 1967. Wetland road crossings: drainage problems and timber drainage. USDA Forest Service Res. Note NC-27.

* USDI Bureau of Land Management. 1979. Wetland-riparian area protection and management. BLM Manual 6740. Washington, D.C.

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*cited in text

Permeable Fill Material 3.15

Purpose

Facilitate water flow through wetland fills.

Description

If fill construction must take place within wetlands, a permeable fill material (such as gravel or crushed rock) should be used for at least the first layer (U.S. Environmental Protection Agency 1975; Thronson 1979; Figures 24 and 25).

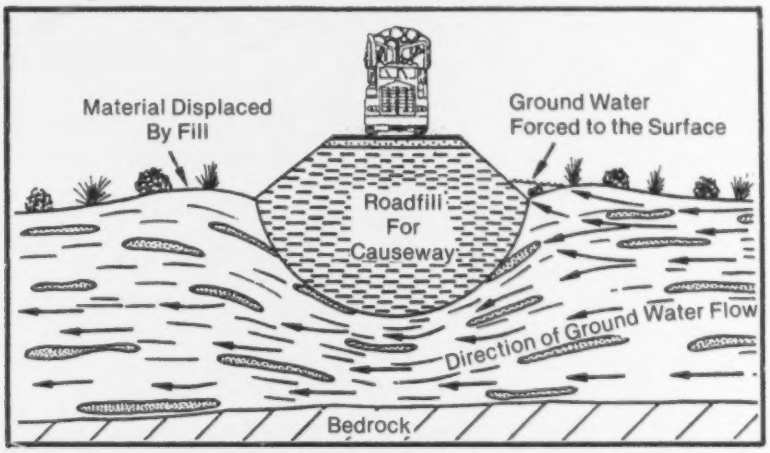

Figure 24 **Impervious roadfill section placed on wetlands consisting of soft organic sediments with sand lenses. The natural material consolidates and restricts ground water flow (Illustration adapted from Thronson 1979).**

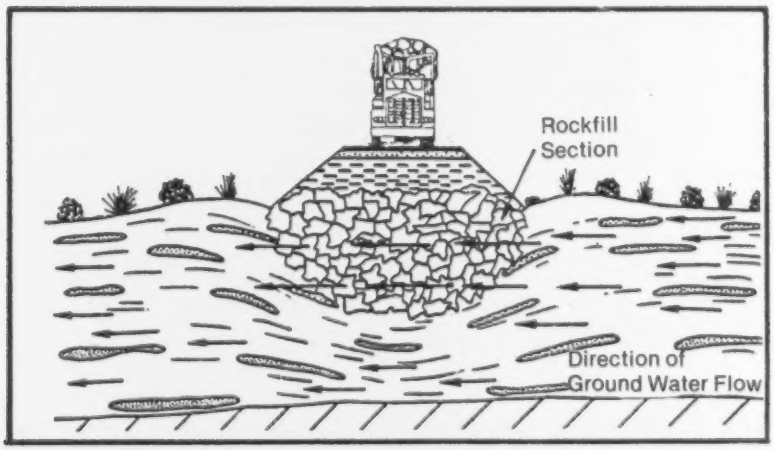

Figure 25 **Pervious roadfill section on wetland allows movement of ground water through it and minimizes flow changes (Illustration adapted from Thronson 1979).**

3.15

Performance

Permeable fill material seems to be partially effective in permitting subsurface water to flow through fills.

Limitations

Permeable fill material is not a substitute for using bridges where needed, or for installation of culverts, adequately spaced and present at all natural drainageways. With time the fill might become clogged with sediment. A dam would form and obstruct flows. Therefore, the BMP should only be used in combination with other mechanisms to insure natural wetland flows.

References

* Thronson, R.E. 1979. Best management practices guidance, discharge of dredged or fill materials. U.S. Environmental Protection Agency Publ. No. EPA 440/3-79-028. Office of Water Planning and Standards. Washington, D.C.

USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720- 100. Washington, D.C. 461 p.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPa 910/9-75-007. Seattle, Washington. 312 p.

*cited in text

Choice of Stream Crossing Structure; 3.16 Fords

Purposes

a) Avoid channel obstructions

b) Provide for fish passage

c) Prevent excessive streambank and streambed erosion.

Description

Traditionally, fords have been considered to be the most environmentally damaging water crossing structure (Michigan Dept. Nat. Res. 1974, Hewlett et al. 1979). However, fords can be the most environmentally effective and cost-effective means under certain, very specific conditions (U.S. Environmental Protection Agency 1975). Such conditions are as follows:

1. The road should not be a major haul road. Secondary forest or farm roads would be amenable to the use of fords.

2. The stream should be intermittent or not contain fish life during low water periods. No flowing water should be present within the channel during use periods for the ford.

3. The streambank, streambed, and approach should consist naturally of extremely stable materials. Bedrock, or thick layers of gravel would be acceptable.

4. Grade of the streambank should not be excessive.

If the above conditions cannot be reasonably expected within the state, it would be most appropriate to prohibit their use, as in Michigan (Michigan Dept. Nat. Res. 1974). However, in some cases, successful stabilization of streambanks and streambeds can facilitate the use of fords.

One such stabilization technique is to pave the ford, with the surface slightly above the streambed. A low water channel would be provided, and covered with grating to facilitate vehicle passage (Evans and Johnston 1980). An alternative would be to use gabions to support the streambed at the ford site. Stream gravel would be used as backfill to form the road surface (U.S. Environmental Protection Agency 1975; Figure 26).

Performance

When properly located, designed, and placed, fords cause a minimum of alteration to the streambank or streambed. The size to accommodate flood flows does not have to be calculated, and the potential for blockage with debris does not have to be addressed (U.S. Environmental Protection Agency 1975). Minimum damage to fisheries has been shown with the use of fords in selected circumstances (Evans and Johnston 1980). Where gabions were tested for utilization in fords, complete healing of the stream bottom was observed within one year (U.S. Environmental Protection Agency 1975). Of all crossing devices, fords are generally the least expensive.

Limitations

The road designer may need to acquire additional information to implement this BMP. Included is data relative to the aquatic biota present in the stream during low water periods, and the stability of streambank and streambed materials.

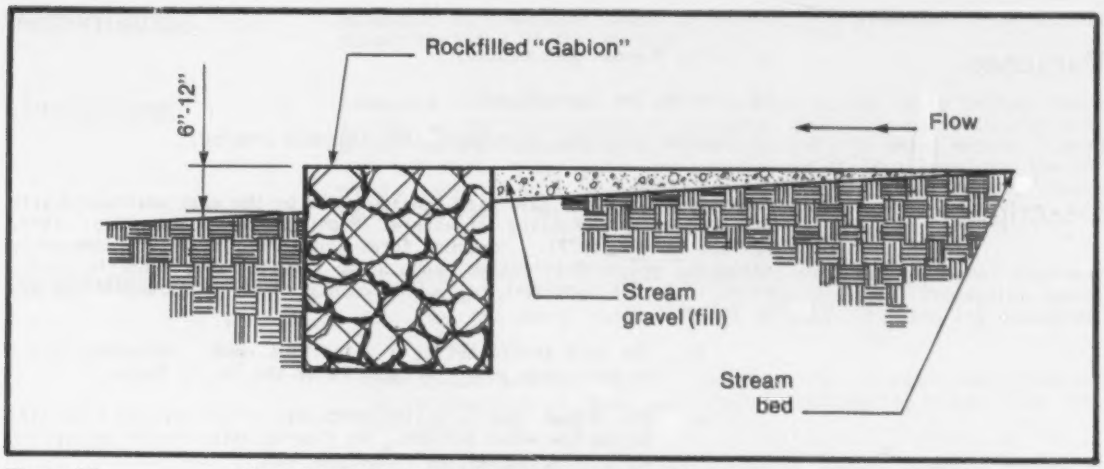

Figure 26 **Use of gabions to stabilize fords. (Illustration adapted from U.S. Environmental Protection Agency 1975). This view is of the stream bed as observed from the stream bank. The stream is flowing from right to left on the drawing.**

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D.C. 63 p. + App. A-F.

* Hewlett, J.D., W.P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia and USDA Soil Conservation Service. Athens. 25 p.

* Michigan Department of Natural Resources. 1974. Rules and regulations concerning Inland Lakes and Streams Act. Hydrological Survey Div. Lansing.

* U.S. Environmental Protection Agency. 1975. Loggings roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

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Timing 4.1

Purpose

To reduce discharge of road fill into streams and wetlands.

Description

Erosion controls, such as mulching, seeding, and structural controls, should be installed concurrently with construction of the roadway. If construction remains uncompleted at the end of the seasonal dry period, the road should be equipped with temporary erosion control devices. During construction, all earth changes should be carefully planned and executed such that soil is exposed for the shortest possible period of time. Permanent erosion control measures should become effective and replace temporary ones no more than 15 days after accomplishing final earth change, and sooner during wet seasons.

Performance

When followed, this is one of the most effective BMPs for protecting aquatic life from sediment. It is recommended in all or part by the states of Michigan (Michigan Dept. Nat. Res. 1977), Georgia (Hewlett et al. 1979), Maine (Kent 1978), New Hampshire (Winkelaar 1971), Washington (Washington Forest Practice Board 1976), and Oregon (Oregon Dept. of Forestry 1980), as well as the Environmental Protection Agency (1975) and the USDA Forest Service (1979).

Limitations

This BMP may present some inconvenience to parties responsible for construction.

References

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Roughening or Scarification of Fill Slopes 4.2

Purpose

To reduce erosion by increasing infiltration of water and retaining planted seeds.

Description

Soil is loosened by means of devices such as deep cleated dozers (traveling up and down slope), and/or bladed machines with ripper attachments. The soil should be loosened perpendicular to the slope so that flow is not concentrated.

Performance

The BMP decreases turbidity and sedimentation in streams, and thus has a positive effect on fish and wildlife.

Limitations

Cost and time are chief limitations. Slope and availability of equipment may also be important. Finally, use of this BMP on unstable soils could result in excessive loosening of the soil, and cause extensive erosion and sedimentation.

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U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

4.3 Mulching

Purpose

To temporarily control erosion of soil exposed by construction activities, disposal areas, borrow areas, and fill slopes.

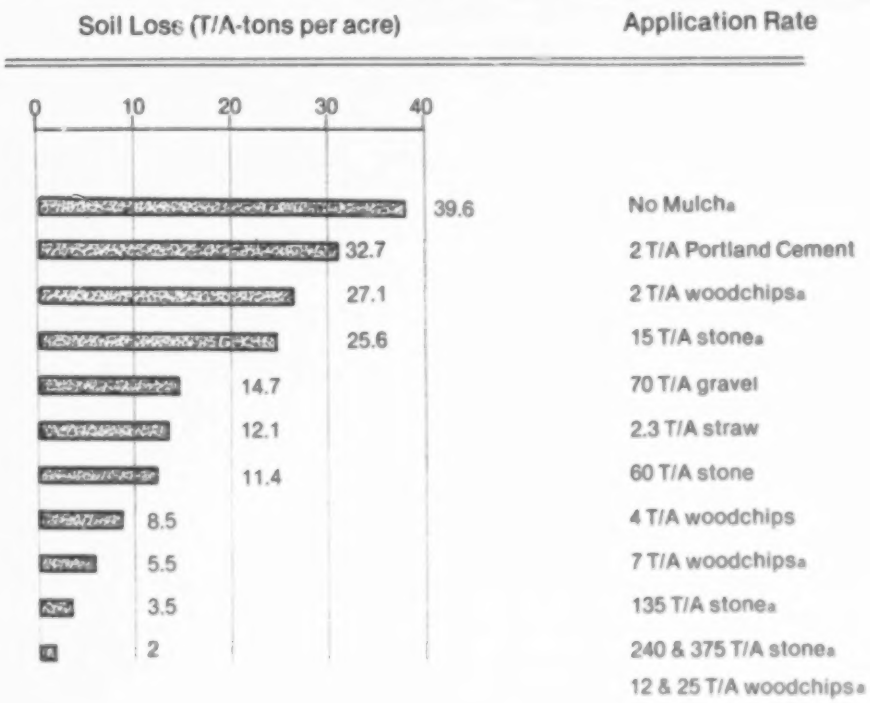
Description

Various materials, including straw, bark, and wood chips, can be used to temporarily stabilize fill slopes and other disturbed areas directly after construction (Haussman and Pruett 1978, Figure 27). In most cases, mulching is used in combination with seeding and planting (BMP 4.4) to establish stable banks. Both the type and the amount of mulches applied vary considerably between regions and depend on the extent of the erosion potential and available materials. On a state or site specific basis, a good deal of information is available through the extension office or USDA Soil Conservation Service to enable choosing the most appropriate prescription for given conditions. Mulches can be spread by hand or machine.

Figure 27 **Machine mulching using straw. (Photo courtesy of the USDA Forest Service).**

Performance

The U. S. Environmental Protection Agency (1975) provided summaries of data evaluating various mulch types from research accomplished by Meyer et al. (1972; Figure 28) and Goss et al. (1970; Table 8). It can be observed from these data that certain types and amounts of mulch can be very effective on a temporary basis for the control of erosion, but that a wide range of results can be obtained. However, both straw and wood chips were effective.



[a]Based on one replication only. Values for other treatments based on average of two replications.

Soil Type: 6-inches silt loam topsoil underlain by compacted calcareous till (AASHO A-4) (Unified ML).

Slopes: Uniform 20 percent

Rainfall Rate:
Simulated rainfall at rate of 2 1/2 inches per hour - 1 hour. the first day followed by two 30-minute applications the second day.

Figure 28 **Soil losses from a 35-foot long slope (Adapted from Meyer *et al.* 1972, as cited by U.S. Environmental Protection Agency 1975).**

Limitations

Slope, soil type, and amount of rainfall all influence the degree to which mulch is effective. Availability of alternative mulches will vary between regions and over time, and thus influence costs.

Table 8. **Erosion control and vegetation establishment effectiveness of various mulches[1] (Goss *et al.* 1970, as cited by U.S. Environmental Protection Agency 1975).**

Function/Soils	Mulches						
	Jute	Excelsior	Straw	Straw & Asphalt	Asphalt	Wood Fiber	Sod
Erosion Control:							
Sheet Erosion-- 1:1 slope	9.0	10.0	8.0	10.0	6.0	3.0	10.0
Sheet Erosion-- 2:1 slope	9.0	10.0	9.0	10.0	7.0	6.0	10.0
Sheet Erosion-- 3:1+ slope	10.0	10.0	10.0	10.0	9.0	10.0	10.0
Rill Erosion -- 1:1 slope	6.0	10.0	8.0	10.0	6.0	3.0	10.0
Rill Erosion -- 2:1 slope	8.0	10.0	9.0	10.0	7.0	5.0	--
Rill Erosion -- 3:1+ slope	10.0	10.0	10.0	10.0	9.0	10.0	10.0
Slump Erosion-- 1:1 slope	10.0	8.0	6.0	7.0	3.0	3.0	8.0
Slump Erosion-- 2:1 slope	10.0	9.0	7.0	8.0	5.0	4.0	9.0
Slump Erosion-- 3:1 slope	SLUMPS USUALLY DO NOT OCCUR.						
Vegetation Establishment:							
1.5:1 glacial till cut slope	7.5	9.0	7.5	8.5	7.5	6.0	--
2:1 glacial till cut slope	8.9	9.5	8.0	9.3	8.7	6.2	--
2:1 sandy loam fill slope	9.0	10.0	9.0	10.0	7.5	8.5	10.0
2.5:1 silt loam cut slope	5.0	10.0	--	7.8	6.0	--	--

[1]Effectiveness rating: 10.0=most effective; 1.0=not effective.

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4.4 Seeding and Planting

Purposes

a) Control erosion originating from fill sites.

b) Provide protection to streams from excessive sunlight.

c) Restore wildlife habitat.

d) Restore fish cover through overhangs into streambeds.

Description

Fills and other areas disturbed by construction can, in most cases, be stabilized through the use of vegetation. Vegetation also assists in the stabilization of roadways and is often used on temporary roads after abandonment (Haussman and Pruett 1978, Kochenderfer 1970; Figure 29).

Seeding and planting prescriptions should be developed from input from plant materials experts, wildlife managers, and fisheries biologists. Forest and farm road managers have ready access to a substantial base of information useful in determining which of the alternative planting prescriptions is most adaptable to their sites.

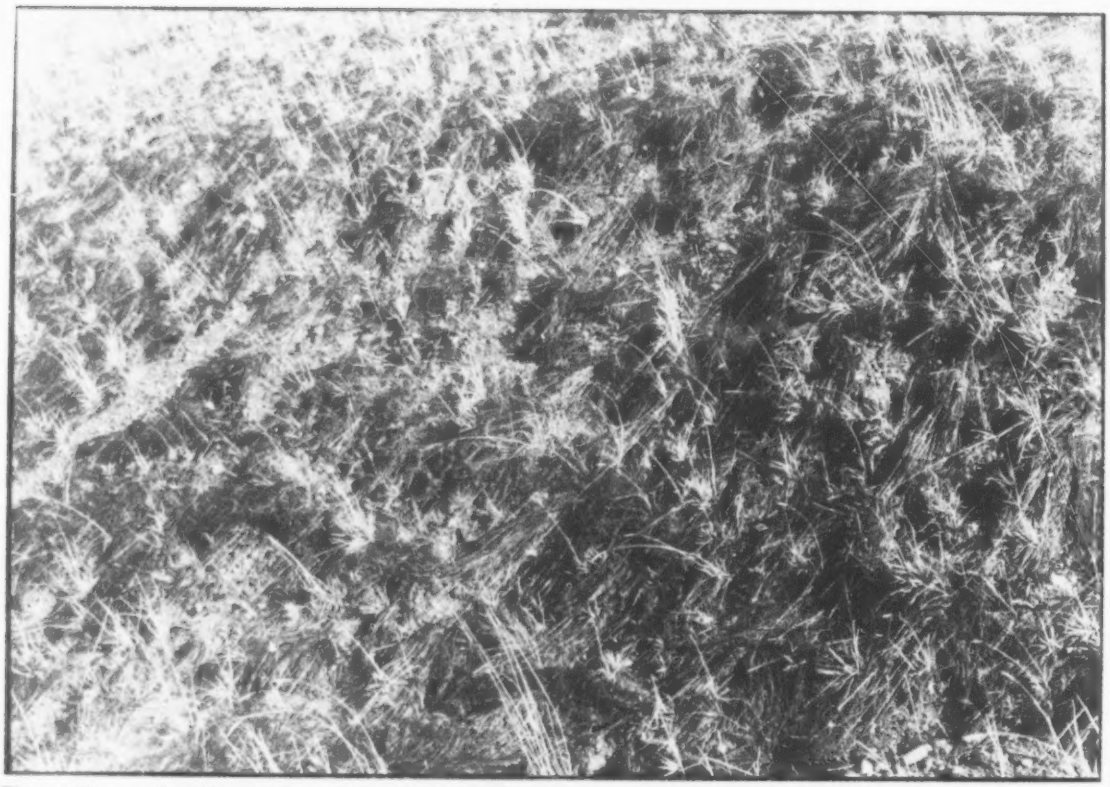

Figure 29 **Seeding protects areas disturbed by construction from erosion (Photo courtesy of the USDA Forest Service).**

Seeding and Planting 4.4

Mixtures of two or more species, and native species, are most often recommended for wildlife purposes (Yoakum et al. 1980). The use of native species is important and practical for at least three reasons:

1. Non-native species can take over and destroy native vegetation. This is especially critical if important natural areas or other ecologically significant or sensitive sites are nearby;

2. The use of non-native species often results in increased maintenance activities and expense; and

3. Plenty of hardy native species are usually available.

USDA Soil Conservation Service technical guides at the statewide level, e.g. USDA Soil Conservation Service (1976); (1978), are excellent sources of information. Excerpts for planting prescriptions for the test states of Michigan and Colorado are provided in Appendices C and D.

In addition to the options of plant species, the method of seeding and timing of seeding, and any supplementary measures such as seedbed preparation by plowing or disking, fertilization, and others should be considered. Alternative methods for planting and seeding include hand operations, the use of a wide variety of mechanical seeders, and hydro seeding. Timing will depend both upon the species to be planted and the schedule of operations which determine when protection is needed. In some cases, double plantings are used; one early planting to establish erosion protection quickly and another, later planting to provide more permanent protection.

In developing seeding and planting prescriptions, the ability of the vegetation to effectively stabilize the soil is of prime consideration. However, possible means to benefit fish and wildlife resources should not be overlooked. Soil stabilization, fish, and wildlife considerations are discussed below.

Slope stabilization. Perennial grasses or grass legume mixtures are generally the most effective types of vegetation for preventing erosion (USDA Soil Conservation Service 1978), and are perhaps the best choice on fill slopes where natural soil structure has been destroyed. However, on streambanks which have been somewhat disturbed by natural processes or by construction, shrubs (including willow, alder, and dogwood) have been shown to be effective in some situations (Van Dersal 1971; Edminster 1950; Lines et al. 1979).

Fisheries. Besides controlling erosion, vegetation along water banks provides shading, opportunities for nutrient transfer between terrestrial and aquatic systems, and fish cover if vegetation hangs over the banks. If temperature reaches levels above tolerance for fisheries, the use of tall shrubs, such as alders or willows, is recommended to decrease water temperature (Evans and Johnston 1980). However, where temperatures are not limiting, increased shade would only detract from overall stream productivity (White and Brynildson 1967). Nutrient transfer is usually best accomplished through the use of tall perennial grasses or low to medium shrubs, which also have a very beneficial effect in providing suitable fish cover (Figures 30 and 31; White and Brynildson 1967).

Figure 30 The lower branches of young alders are alive and drape into the water, providing good trout cover. (Photo courtesy of the Wisconsin Department of Natural Resources).

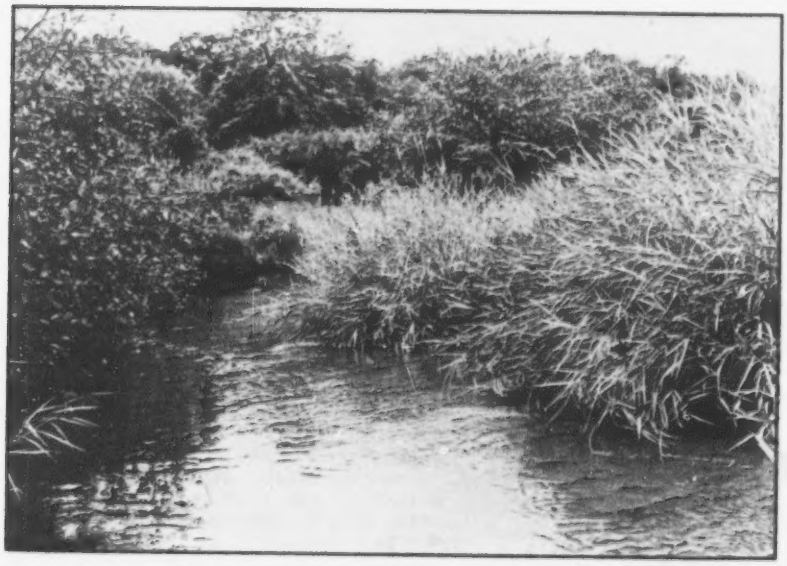

Figure 31 Reed canary grass provides good shelter at the edge of a stream (Photo courtesy of the Wisconsin Department of Natural Resources).

Wildlife. The use of vegetation for wildlife management has long been accepted as one of the most effective means to increase productivity. However, wildlife needs for various types of vegetation vary considerably between species. Therefore, before developing a seeding and planting BMP which considers wildlife, management objectives should be made clear. Plants can be selected on the basis of value to selected species, to a group of species, or to ecosystem diversity. Moreover, planting for wildlife can be accomplished for food, cover, or overall habitat values.

Planting disturbed slopes with wildlife food plants can be somewhat counter-productive, unless only the fruits of woody or perennial vegetation are used as food. Otherwise, wildlife can destroy the vegetation through overutilization, and thus nullify any value the plantings had for slope stabilization. Such is especially the case with some legumes, which are highly preferred by big game (U.S. Environmental Protection Agency 1975). Perennial grass legume mixtures can be used to stabilize soils and to provide nesting cover for dabbling ducks in the prairie pothole region (Duebbert and Lokeman 1976, Voorhees and Cassel 1980). In Illinois and Colorado, similar vegetation is used by pheasants for nesting (Joselyn et al. 1968, Joselyn and Tate 1972, Snyder 1974).

Shrub vegetation has long been recognized for its value to nongame birds (Edminster 1950, Besadney et al. 1968). In the western states, the cottonwood/willow habitat type has been noted as highly productive for nongame birds (Beidleman 1978, Bottorff 1974; Conine et al. 1979, Dembosz et al. 1971; Engle-Wilson and Ohmart 1979; Fitzgerald 1978, Gaines 1974; 1977), and serious thought is being given to favoring it where possible (Anderson et al. 1979).

Performance

Vegetative stabilization has been shown to be the most effective erosion control method when appropriate prescriptions are made and followed (Lines et al. 1979). It also can provide the various side benefits to fish and wildlife, as described above. However, due to the degree of dependence vegetation has on site conditions, results have not always been predictable (Yoakum et al. 1980). The establishment of vegetation was recommended by virtually all agencies whose BMPs were examined.

Limitations

Individual prescriptions are limited by a wide variety of factors, including the following:

Technical. In some areas, vegetation could obscure vision and present a safety hazard. In most cases, however, this problem can be alleviated with appropriate planting prescriptions of low-growing species that will not obscure vision.

Soils. Several soils variables influence the degree to which specific plants are adapted to specific sites. Among them are drainage, soil texture, and fertility. Plant prescriptions should be keyed to these variables.

Slope. Slope affects vegetation success because plants on steep slopes need to have more soil-holding capability than on gentle slopes. Moreover, the process of planting is made more difficult on steep slopes. In Michigan, a maximum slope of 1:2 is recommended for vegetation purposes (USDA Conservation Service 1978).

Hydrology. Under high current velocities, establishment of vegetation is difficult, if not impossible. Lines et al. (1979)

recommended that, in Oregon, structural means should be substituted for willow establishment where stream velocities exceed 5 to 6 feet per second.

Climate. Both temperature and amount of moisture influence plant response. Since this response varies considerably between species, correct prescriptions should consider this.

Wildlife. Habitat and food needs vary between wildlife species, so management objectives for seeding and planting BMPs need to be developed before BMPs are drafted. In some situations, wildlife could detract from the erosion control function of plantings by consuming plants valuable as food. Where inordinate wildlife numbers are attracted to the road, a hazard could be created for both the road users and the wildlife.

Aquatic ecology. The degree to which fisheries need protection from elevated water temperature, cover, and require the nutrient transport provided by vegetation will vary from region to region, and from stream to stream.

In Oregon, Lines et al. (1979) reported a cost of $1.50 per foot or $6,000 per acre for shrub establishment. Nelson et al. (1978) listed costs of grass establishment as $540-$700 per acre, while the combination of grass and woody vegetation cost $1,620-$2,100 per acre. Although costs vary considerably, they are significantly less than structural erosion control measures (Lines et al. 1979).

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Submerged Burlap Strips 4.5

Purposes

a) To provide temporary erosion control of fill material on semi-arid, difficult to vegetate sites.

b) To facilitate permanent erosion control through vegetation establishment.

Description

Fill slopes in semi-arid climates may be difficult to vegetate because insufficient water is available for rapid growth, even though the site may be adjacent to a waterway. In this instance, a series of burlap strips can be set vertically into the ground and perpendicular to the direction of flow (Figures 32 and 33; Heede 1975). A portion of the burlap strip is left protruding above the ground, and acts as mechanical reinforcement to the upper soil mantle. The site is then seeded or planted using considerations specified in BMP 4.4. The strip serves to bar surface soil movement, and thus enhances the ability of plants to develop root systems sufficient to control erosion. The strips are placed in layers, so that the protrusion retains its stiffness for approximately two years and functions effectively for 5-6 years.

In the design of these strips, how deep to insert the burlap strip and how far above the soil to allow the strip to protrude should be modified taking into consideration cost, installation time, and the site-specific factors of slope angle, geologic structure, and degree of soil solifluction. For tests in Colorado and New Mexico, strips were installed 10 inches deep with a 1-3 inch protrusion. Such a design was adequate when rill depth is less than 5 inches, but would not be adequate if erosion channels exceeded 10 inches in depth.

Performance

Heede (1975) found that submerged burlap strips, when combined with vegetation, were effective in controlling erosion on a road cut in New Mexico, and on man-made waterways in the Colorado Rocky Mountains. Although initial soil disturbance was higher on experimental areas than on control areas, burlap strips did facilitate better erosion control over the long term. The effectiveness of burlap strips was related to the ability to establish vegetation for erosion control after the burlap strips had decayed.

The use of burlap strips enables vegetative, rather than structural, erosion control in some situations where the establishment of vegetation would otherwise be difficult. This provides a distinct advantage in that vegetation can provide fish and wildlife habitat, while structural control generally reduces an area's habitat value.

Limitations

In wet climates where revegetation is not a problem, submerged burlap strips would not provide a useful function commensurate with their cost. Their use should be restricted to areas which have only shallow gullies and sites that, if the soil surface is stabilized, could be effectively vegetated within 5-6 years.

If the treatment is misapplied, erosion control measures could be ineffective and thus have to be reapplied. However, Heede (1975) found that the strips were effective at halting erosion from sites that had been subjected to erosion for one year. If erosion progressed to the point where erosion channels exceed 10 inches in depth, the site would have to be prepared by filling, plowing, and/or disking (in order to remove the channels) before installation of the strips.

Figure 32 Looking at a submerged burlap strip installed on waterway No. 6 on Alkali Creek watershed. Arrow indicates the direction of flow (Heede 1975).

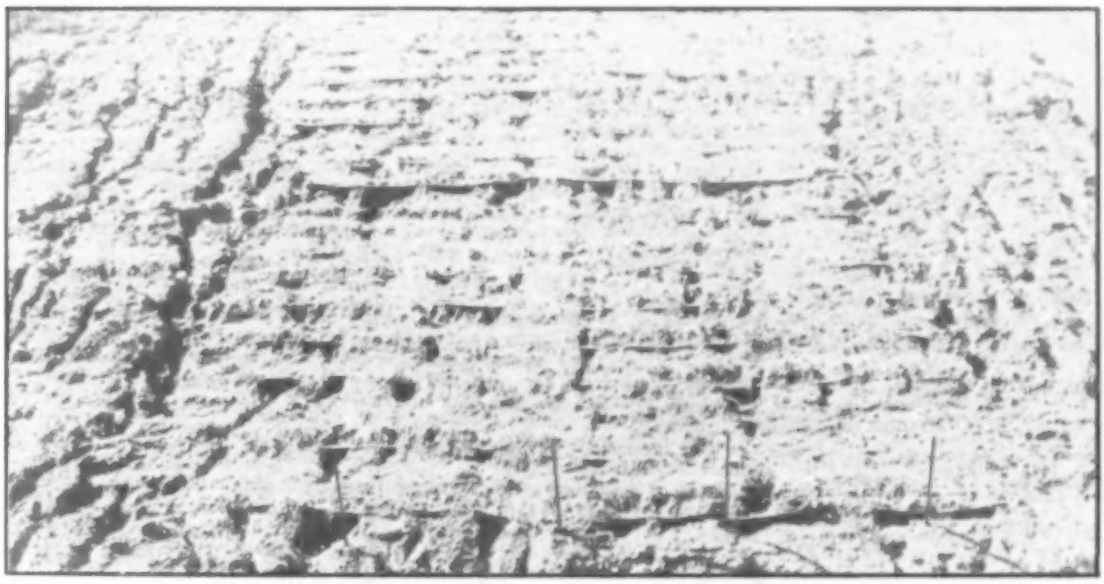

Figure 33 The road-cut burlap plot 1 year after treatment. Continuous rills and gullies did not develop. Stakes in foreground and on crest of slope are transect markers (Heede 1975).

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4.0 Erosion Control Measures

4.6 Riprap

Purpose

To reduce erosion of fill slopes caused by stream currents, precipitation, and groundwater discharge.

Description

Stones of suitable size are fitted and implanted in the slope to form a contiguous cover (Figure 34). Riprap should be extended below the scour depth of the stream channel, and above the high water line (Hansen 1968). Commonly, a filter cloth or graded filter blanket of small gravel is laid beneath the riprap.

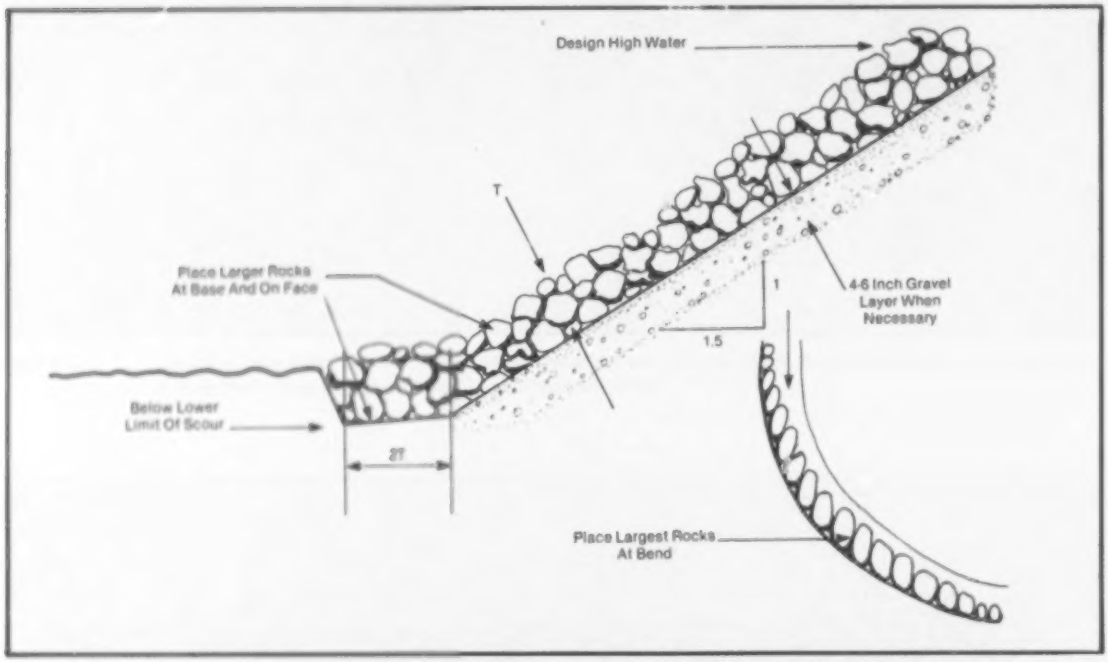

Figure 34 **Dimensions of typical rock riprap blanket. T equals 1.5 times the diameter of the average size rock. When rock is spherical cobbles, or when machine-placed, T = 1.9 D (Illustration adapted from Hansen 1968).**

Riprap should be as free as possible from weakly structured rock, soil, organic material, and rock of insufficient size. Hansen (1968) provides a means for determining appropriate size of riprap which is based on bank face slope ratio, water velocity, and the specific gravity of the rock (Figure 35). However, this graph calculates only the minimum weight of the rock. Two-thirds of the rock should be heavier than this.

Largest rocks should be placed at the bottom of the slope and on the bend of curves. If riprap must be used to stabilize fine sands or silts, uniformly-sized stone should not be used. Riprap should not be used on slopes which are naturally subject to deep-seated or avalanche-type slide failures. Preferably it should be used in conjunction with other slope stabilization techniques and then only if these techniques are ineffective alone.

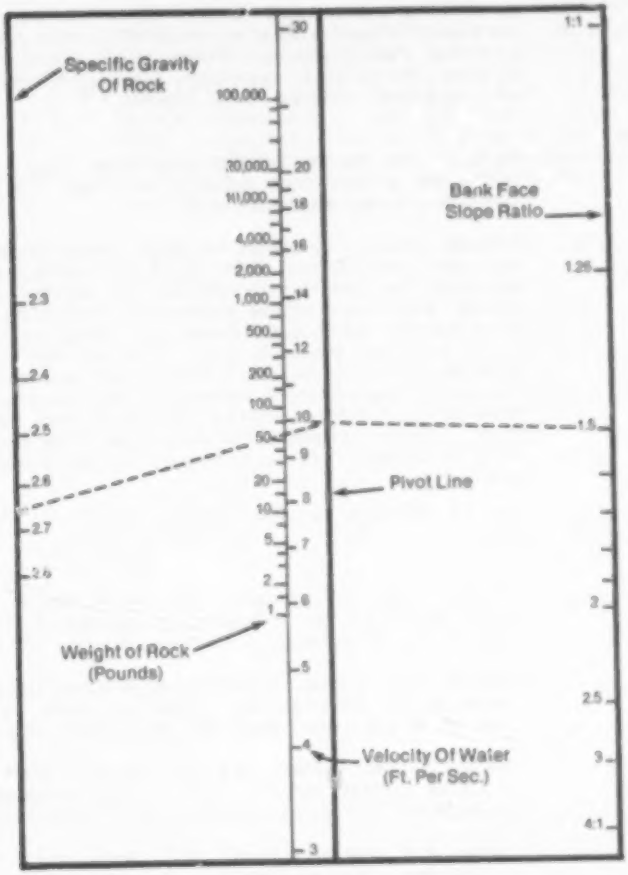

Figure 35

Alignment chart for determining weight of stone to be used for riprap. Example: Find bank slope ratio (1.5:1) on righthand scale. Extend line to appropriate water velocity (10 feet per second) on right side of center scale. Find specific gravity of rock (2.65) on lefthand scale. Extend line to intersect first line at "Pivot line". Read weight of rock (57 pounds) where second line crosses center scale (Illustration adapted from Hansen 1968).

Performance

If installed properly, this BMP is slightly to moderately successful in curbing sediment damage to fisheries. It is more effective at minimizing erosive force of rainfall than in slowing sheet erosion. It is recommended by USDA Forest Service (1979) and EPA (USDI Federal Water Pollution Control Administration 1970). For fisheries, riprap habitat may provide habitat for food chain organisms, such as mayflies and caddisflies (Witten and Bulkley 1975). However, where cover is limiting, the undercut banks, which riprap is used to correct, often serves

as valuable and critical cover. For wildlife, riprap often results in the loss of riparian habitat, especially where revetments are constructed higher than necessary. Forbes et al. (1976) found a marked decrease in bird life in areas associated with revetments. Hurst et al. (1980) confirmed these results for California.

Limitations

Riprap is not recommended for very steep slopes or fine-grained soils. It is not a long term solution to slope instability. Stones of a suitable size may be unavailable.

Although potentially useful in those situations where seeding, planting and other nonstructural BMPs would be ineffective, this BMP also has potential for destructive effects to wetland and riparian wildlife habitat and stream bottom habitat for fisheries. Even if placed well above the high water mark, stones will sooner or later enter the stream. There, they may diversify habitat or, at least as likely, block fish movements, fill in valuable pools, and interrupt the balance between erosion and deposition of sediments. When placing stones below the high water mark, localized erosion and short term turbidity problems will occur. There is some likelihood that flow and circulation patterns could be altered. If so, this activity would require a dredge and fill permit.

Cost is estimated by Keown et al. (1977) at $3.75 - 32.00 per cubic yard.

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4.7 Terraces, Diversions, Deflector Dikes, Slots, and Layways

Purpose

To reduce erosion of fill slopes by storing, diverting, or reducing velocity of runoff.

Description

These features are channels which generally follow the slope contour and have a supporting ridge on the downhill side (Figure 36). They are constructed atop or across cut or fill slopes. Terraces generally are level and have open or closed ends to retain the runoff. They are used to break up slope lengths.

Figure 36 Log diversions providing temporary erosion control on a disturbed stream bank (Photo courtesy of the USDA Forest Service).

Terraces, Diversions, Deflector Dikes, Slots, and Layways 4.7

Diversions are open-ended and carry excess water at nonerosive velocities to planned disposal areas. Suitable disposal areas consist of natural drainageways or low-gradient upland areas between drainage channels.

Performance

Although rather temporary, this BMP may be moderately successful in curbing sediment damage to fisheries. It is recommended by the U.S. Environmental Protection Agency (1975).

Limitations

No significant adverse impacts are likely to occur under normal circumstances. However, if a high density of these features are used in a single watershed, peak flows may be lowered as runoff is retained. The scouring effect which otherwise would be present may be vital to the long term stability of stream invertebrate communities.

This BMP is not applicable for unstable soils and steep slopes.

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4.8 Gabions

Purpose

To control erosion from streambank fills, to support fords, and to restore a stream's pool/riffle ratio.

Description

Specifications for gabions used for erosion control (Figure 37) are presented in USDA Forest Service (1979). Basically, they are at least 3 feet wide by 6 feet long by 3 feet high. Rocks of 6-12 inches in diameter are contained by 11-gauge wire mesh with 4-inch openings, and the cage is firmly anchored to the stream bed. Rocks are added after the cage has been implanted and lids are closed in a downstream direction.

Gabions used for stream improvement consist of a rectangular rock-filled basket of wire mesh, with dimensions 6 1/2 x 1/2 x 1/2 feet. Two such baskets are stacked vertically with their long axis perpendicular to the stream flow. The upstream edge is set into the streambed, sloping upward from front to back. To reduce scour, a rubber mat is attached and extends from just in front of each structure into a slot and through the top gabion.

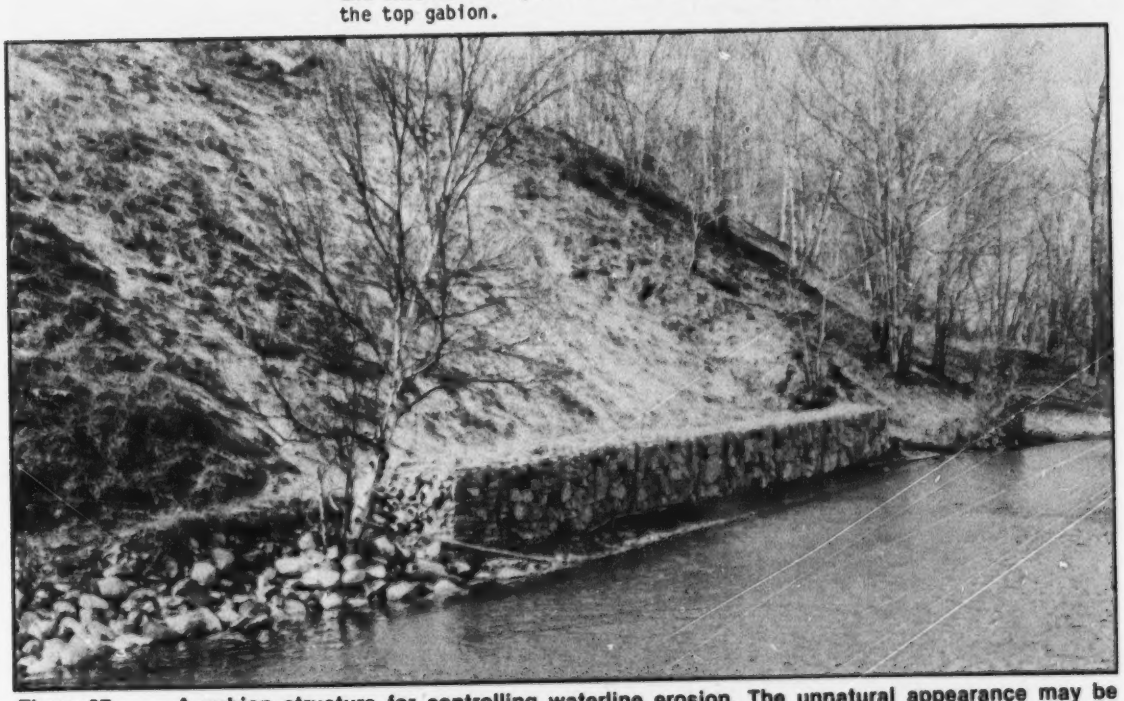

Figure 37 **A gabion structure for controlling waterline erosion. The unnatural appearance may be undesirable in some situations (Photo courtesy of the USDA Forest Service).**

Performance

When used and maintained under the proper circumstances of location, current, and substrate type, gabions may be slightly to moderately effective in stabilizing streambanks. They are recommended for erosion control by the USDA Forest Service. However, gabions, as well as other structural control devices have been shown to have a negative effect on wildlife, since they destroy riparian wildlife habitat (Forbes et al. 1976; Hurst et al. 1980).

Gabions 4.8

Properly constructed gabions can provide a substrate attractive to pioneering stream invertebrates which are important colonizers of areas denuded by sedimentation. They also create pools essential to many fish, especially in swift waters.

Limitations

Gabions should be used for erosion control only when the source of streambank erosion (e.g., deflected current) cannot be corrected by other, more natural means. This is because the erosion and deposition are natural processes which can only be redirected, not controlled. Poorly considered placement of gabions may increase erosion in unintended areas, or cause siltation of spawning areas. Stones of suitable size and quality may be unavailable. Keown et al. (1977) estimated cost at $43-$50 per cubic yard.

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5.0 Construction Operations

5.1 Timing

Purpose

To minimize sediment, flow alteration and disturbance of fish and wildlife during sensitive seasons.

Description

Road construction should be accomplished during seasons not prone to severe erosion or sensitive to fish and wildlife. The most often recommended seasons to avoid are:

1. Wet seasons (Beckett Jackson Raeder, Inc. 1979; USDA Forest Service 1979a; Washington Forest Practice Board 1976).

2. Periods of fish migration and spawning (Evans and Johnston 1980).

In selected instances, the following periods may also be determined to be sensitive:

1. Low water periods would be extremely sensitive to fishes, if a source of naturally occurring cool water existed immediately downstream of the construction site. In areas where summer water temperatures and water levels make many streams uninhabitable for fishes, especially salmonids, they congregate at spring seeps and at the mouths of small tributaries. Sites immediately upstream from these areas should not be subjected to construction activities during low water periods.

2. If wetlands important to waterfowl, colonizing shorebirds, or raptor nesting must be crossed by a road, periods for nesting and brood rearing should be avoided. This is a type of area, however, that should be avoided completely (BMPs 2.1 and 2.2).

3. Under circumstances where big game winter ranges must be crossed, winter would be a sensitive period. Once again, it is recommended that it would be best to avoid these areas completely.

The exact dates for these sensitive periods vary considerably between states, and in some cases, between regions within states. Therefore, appropriate dates should be determined from seasonal or monthly rainfall data for the differentiation between wet and dry seasons. State fisheries and wildlife biologists, experienced with the regional conditions, could be most helpful in specifying critical periods.

Performance

Depending on the species and the type of activity proposed, the efficacy of this BMP may range from large (e.g., bald eagle nesting, young not yet fledged) to slight. This BMP is recommended by the states of Washington (Washington Forest Practice Board 1976), Maine (Kent 1978), Florida (Florida Division of Forestry, n.d.), and New Hampshire (Winkelaar 1971) as well as the USDA Forest Service (1979a, 1979b) and the U.S. Environmental Protection Agency (1975).

Limitations

Annual rainfall pattern is the most important physical variable to consider when developing this BMP. Biologically, periods of fish migration and spawning, waterfowl and other bird nesting, rearing, and periods of winter stress need to be considered.

Timing 5.1

If all constraints were applied to every single site, a resulting situation could easily mean that no time, or sufficiently long periods of predictable time, would be available for road construction at any site. Therefore, it is important for the road planner to know what biological resources are of concern at any given site. A consultation process would serve a valuable purpose to this end.

From a technical standpoint, timing restrictions, if not considered early in the process of scheduling activities, could result in significant down time, and thus, increase costs for road construction.

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5.2 Pioneer Roads

Purposes

a) To reduce the amount of area disturbed.

b) To ensure stability of the area involved.

Description

Pioneer roads are temporary access ways used to facilitate construction equipment access for the building of the permanent roads. They should be confined to the surveyed permanent roadway construction limits. During work, the designated final cut slope should not be undercut. Deposition of materials outside the roadway limits should be avoided. The pioneer road should be fitted with temporary drainage structures.

Performance

The BMP reduces turbidity, sedimentation, temporary loss in wildlife habitat, shoreline erosion, and thus generally had beneficial effects to fish and wildlife. The USDA Forest Service (1979a) developed this standard for use nationally. It was evaluated and determined appropriate for inclusion into a system of BMPs for the Pacific Southwest Region in California (USDA Forest Service 1979b).

References

* USDA Forest Service. 1979a. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720-10. Washington, D. C. 461 p.

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Restrictions on Machinery Operations 5.3

Purpose

To reduce turbidity and alteration of bottom habitats in streams and wetlands.

Description

Machinery used for placing culverts, constructing bridges, etc. should not be operated below the ordinary high water mark of streams or wetlands unless absolutely necessary (Figures 38 and 39). If such activities are necessary, a dredge and fill permit might be required. When machinery use below the high water mark is unavoidable, activities should be limited. Bridge excavation should not occur outside of cofferdams or caissons. Abutments should be constructed from the streambank rather than the streambed.

Performance

This BMP is highly effective in curbing damages to aquatic biota. Wooldridge (1979) found almost a hundredfold increase in suspended solids while bulldozers were operating in a stream during culvert installation. Further, effects of bulldozers in streams are documented by Warner and Porter (1960). This BMP is recommended by the states of Georgia, North Carolina, Oregon, and Washington, as well as by the USDA Forest Service and EPA.

Figure 38 **Extensive encroachment of machinery into the stream and associated riparian zone caused water quality impairment and will subject the streambank to significant erosion (Photo courtesy of the USDA Forest Service).**

5.3

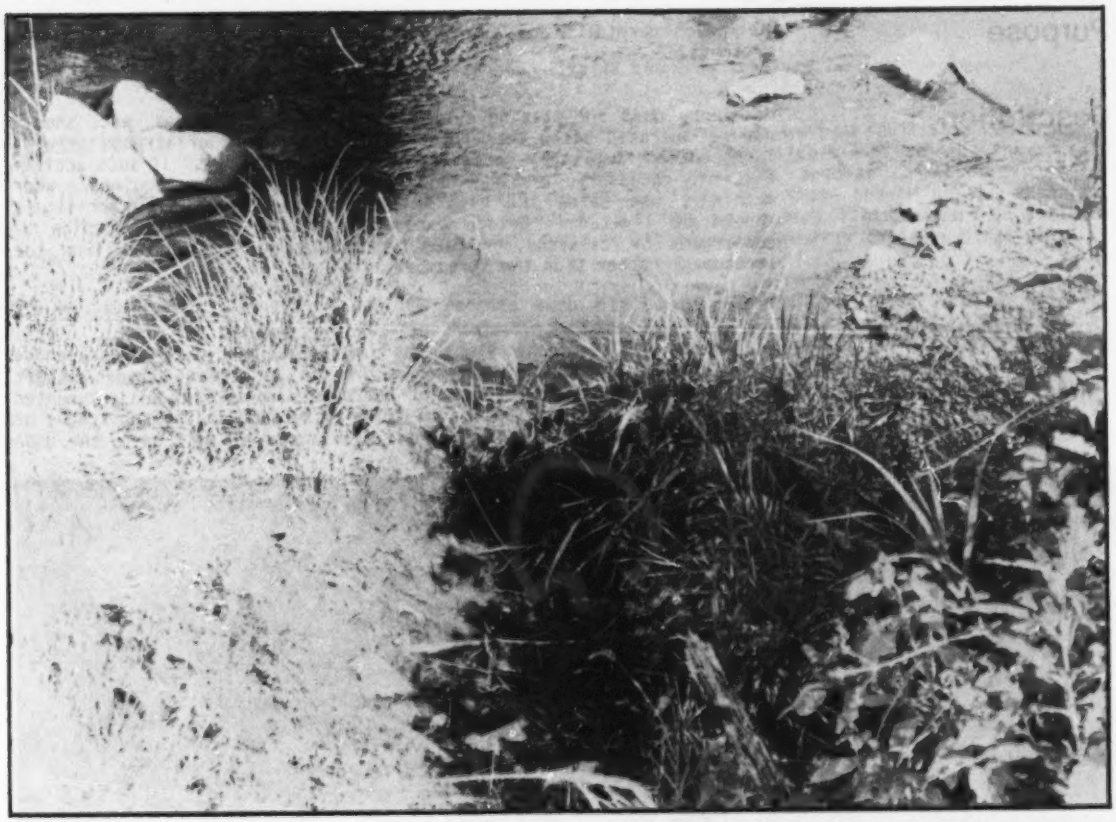

Figure 39 **This streambank rut was caused by one bulldozer crossing the stream indiscriminantly on one occasion. Repeated crossings at the same location would greatly increase the damage (Photo by J.R. Hynson).**

Limitations

The narrower the water body, the easier it would be to conform to this BMP. It may be impossible to avoid machinery operation in very wide streams or wetlands.

This is one of the most important and effective BMPs, but also one of the more difficult ones with which to comply. Instances where intrusion into the stream can be essential are difficult to specify beforehand. Also, in a very few instances, greater damage may be done by machinery operating in riparian habitats than if operations had been conducted from the stream.

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* Warner, K. and I.R. Porter. 1960. Experimental improvement of a bulldozed trout stream in northern Maine. Trans. Amer. Fish Soc. 89(1):59-63.

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* Wooldridge, D.D. 1979. Suspended sediment transport and forest road construction. Wildhorse Creek, Kaluma River Basin. Washington Dept. of Ecology Report 79-5a-1.

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5.4 Use of Temporary Bridges

Purpose

To prevent streambank erosion, disturbance of stream bottom, and excessive turbidity.

Description

Log bridges consist of logs bound together and suspended above the stream (Figure 40), with no part in contact with the stream itself (BMP 3.3). They should be used when repeated stream crossings are needed in order to install a permanent culvert or bridge.

Performance

Temporary bridges are highly effective in curbing damage to streams as an alternative of operating machinery in streams and wetlands. They are recommended by the USDA Forest Service (1973).

Limitations

They should not be used if peak flow or severe storms are expected during the period of use, as they may block fish passage or cause flooding if washed out.

Figure 40 A temporary forest road bridge made mostly from nearby trees. The bridge easily supports a 15 ton bulldozer (Photo courtesy of the USDA Forest Service).

References

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5.5 Organic Debris Disposal

Purpose

a) Insure fill stability.

b) Prevent debris from entering streams and causing channel obstruction, obstruction of fish passage, and downstream damage from surges after dam failure.

c) Control erosion.

d) Remove barriers to movement for big game.

Description

Several alternatives are available for the disposal of organic debris generated during the course of road construction. However, these alternatives do not include the use of debris as fill material for permanent roads or for temporary roads constructed across known areas of unstable soils and where possible construction failure would directly impact waters, since the organic material would eventually decompose and cause fill failure. Timber could be used for upright support structures for swampy ground crossing or for culvert protection (USDI Federal Water Pollution Control Administration 1970; Washington Forest Practice Board 1976).

Useable materials, e.g., timber, pulpwood, and firewood, should be decked in suitable locations and utilized to the extent possible. Alternatives for use of other materials include piling and burning (Figure 41), chipping (Figure 42), burying, scattering, windrowing, disposal in cutting units, and removal to designated spoil sites (BMP 2.6)(USDA Forest Service 1979a: 1979b).

Figure 41 Burning is a technique for disposing of organic slash. (Photo courtesy of the USDA Forest Service).

Figure 42 **Disposal of organic debris through chipping (Photo courtesy of the USDA Forest Service).**

In erosion prone areas or where reduction in the width of the buffer strip is absolutely necessary, organic debris piled, scattered, or windrowed can be used in conjunction with seeding to stabilize fill slopes (Packer and Christensen 1964; Kochenderfer 1970; Hewlett et al. 1979; North Carolina Division of Forest Resources 1979). However, this should be considered as a last resort, and not a substitute for proper road location.

Windrowing or piling can be used as a wildlife management technique for small game and birds (Yoakum et al. 1980). However, it should not be used where it could block migration routes or other movement patterns of big game (Lyon, in press). Any form of on-site disposal which creates a fire hazard should be avoided.

Performance

Prohibiting the use of organic debris in fills reduces the possibility of later fill failure. During the use period of the road, organic material would decay and cause gaps in the fill material which would

5.5 Organic Debris Disposal

eventually fail (USDI Federal Water Pollution Control Administration 1970).

Providing for the use of appropriate material would generally cause less need for disposal and would facilitate the use of valuable resources.

All other options have been used viably and been proven over many years, although little has been published. Perhaps the most controversial of the two options is windrowing and piling, which could be considered a positive aspect of small game management (Yoakum et al. 1980), or a detrimental barrier to big game (Lyon and Jenson 1980; Lyon 1976, Lyon and Basile 1979).

Limitations

Providing for the use of debris might cause additional area to be disturbed if access were not controlled.

The use of piling and burning may be prohibited or regulated under provisions of the Clean Air Act or state clean air requirements. The most common constraint deals with timing. Burning would be permitted only under certain weather conditions and at certain times. Burning should not be conducted in locations where the ashes might be washed into streams. Burning, and to a lesser extent piling, windrowing, or scattering may cause water chemistry effects to the stream by providing a pathway for entry of ashes or debris into the waters. On the other hand, complete removal of all debris from the area could decrease nutrient transfer from terrestrial to aquatic systems.

As described earlier, the use of windrowing and/or piling needs careful assessment. Excessive slash or slash piles (over 0.5m) have been shown to be a barrier for elk (Cervus canadensis) and mule deer (Odocoileus hemionus) (Lyon 1976; Lyon and Jenson 1980) and could be a barrier for other species as well.

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5.6 Diversions and Dewatering

Purposes

a) Prevent construction sediment from entering streams.

b) Maintain instream flows.

c) Protect fisheries resources.

Description

At construction sites for water crossings, water should be diverted around the area of earth change (USDA Forest Service 1973). Such diversions should have prior written approval from the state fisheries biologist (USDI Federal Water Pollution Control Board 1970; USDA Forest Service 1973). All water diverted from its natural channel should be returned via culvert, flume, spillway, or the equivalent (Washington Forest Practice Board 1976).

Thronson (1979) portrays one procedure for diversion for culvert installation in a small stream (Figure 43). First, a diversion channel is excavated and protected from erosion. A temporary dam is installed on the upstream end of the channel to prevent water flow during excavation. Once the channel has been created, the dam is broken and water allowed to flow through the channel. The culvert and fill is installed in a dry channel. The diversion is dammed again and water again flows through the natural channel. The last step includes filling of the diversion.

For bridge construction on larger waters, cofferdams or caissons are used (Figure 44). Such structures should be constructed before commencing any excavation of the stream bank, and should be made out of steel, concrete, or wood. Water within the cofferdam should be pumped to a water disposal site to filter sediment, and then returned to the stream. The stream bank at the construction site should be stabilized prior to removal of the cofferdam (Michigan Dept. of Natural Resources, n.d.).

Performance

Properly constructed and stabilized diversions reduce sedimentation and turbidity downstream, and thus benefit fisheries resources. However, improperly designed diversions may increase sedimentation and turbidity.

Limitations

All construction activity should be timed for periods of low flow. Diversions should only be used where construction requires instream disturbances. Precautions should be taken to ensure that diverted water is of good quality and fish migration routes would not be obstructed during critical periods.

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Diversions and Dewatering 5.6

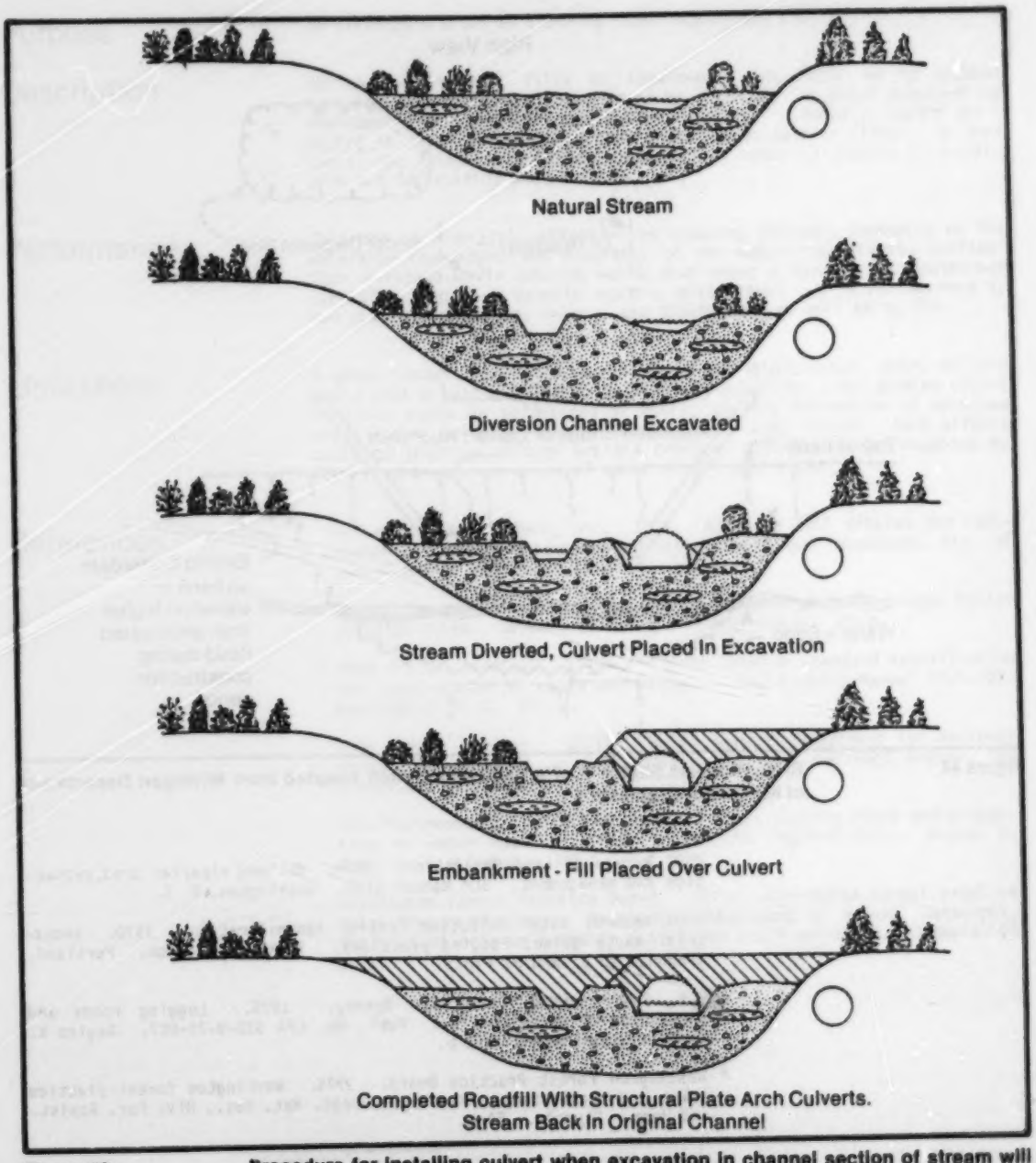

Figure 43 **Procedure for installing culvert when excavation in channel section of stream will cause sediment movement and turbidity increases (illustration adapted from Thronson 1979).**

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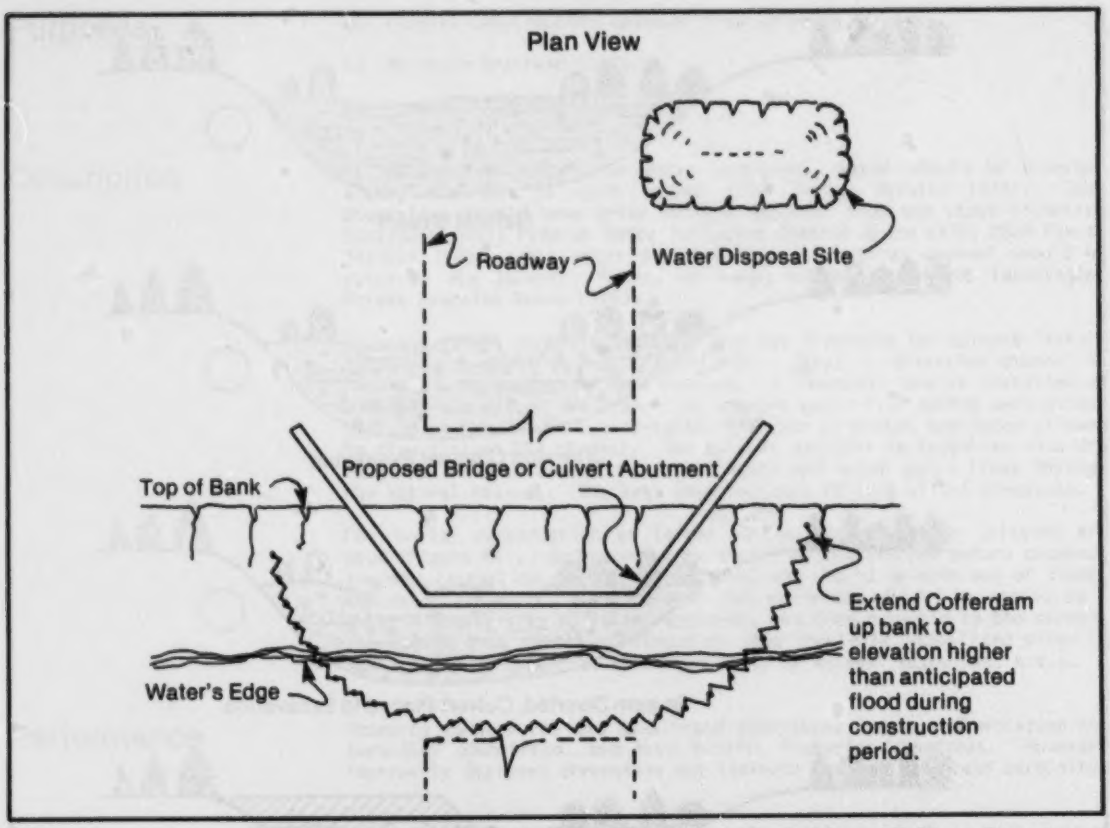

Figure 44 **Bridge/Culvert Sketch (Cofferdam) (Illustration adapted from Michigan Department of Natural Resources n.d.).**

USDI Bureau of Land Management. 1979. Wetland riparian area protection and management. BLM Manual 6740. Washington, D. C.

* USDI Federal Water Pollution Control Administration. 1970. Industrial Waste guide; logging practices. Northwest Region. Portland, Oregon. 40 p. and 37 Figs.

U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910-9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. For. Assist. and Regs. Olympia. 54 p.

*cited in text

Compacting of Fill 5.7

Purpose

To minimize erosion by insuring stability of the fill.

Description

During construction, fills or embankments are built up by gradual layering. Each layer is compacted by a tractor or other construction equipment over the entire surface of the layer. Commonly, layers are 6 inches in depth before compacting (USDA Forest Service 1979a). In some cases, the final layer is not compacted in order to provide an acceptable bed for seeding and planting.

Performance

This BMP is moderately effective in reducing erosion, depending on the watershed topography and proximity of the water table to the surface. Such a reduction in erosion would also cause a decrease in downstream turbidity, and thus benefit aquatic ecosystems. It is recommended by the states of Michigan, Oregon, and Washington, as well as by EPA.

Limitations

A minor interference with surface drainage might occur, which in turn would have a variable effect on fish and wildlife. The damming effect of fills would be heightened slightly, causing inundation of upstream areas and draining of downstream areas to a minor extent. Such effects could be positive through wetland creation upstream and/or negative by depriving downstream areas of water at historic rates.

References

Beckett Jackson Roeder, Inc. 1979. Michigan soil erosion and sedimentation control guidebook. Michigan Dept. Nat. Resources, Div. of Land Resource Programs. Lansing. 108 p.

Oregon Department of Forestry. 1980. Field guide to Oregon forest practice rules. Seventh Revision. Salem, Oregon. 59 p.

* USDA Forest Service. 1979a. Forest Service standard specification for construction of roads and bridges. Engineering Manual 7720-100. Washington, D. C. 461 p.

USDA Forest Service. 1979b. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Department of Natural Resources, Division of Private Forestry Assistance and Regulations. Olympia. 54 p.

*cited in text

5.8 Culvert Installation

Purposes

a) To protect aquatic, wetland, and riparian systems from alterations due to flow changes.

b) To facilitate fish passage.

c) To prevent erosion, turbidity and sedimentation effects caused by culvert failure.

Description

If possible, culverts should be installed within the natural stream beds. The inlet should be on or below the streambed to minimize flooding damage to upstream terrestrial wildlife habitat (Stoeckler 1965) and to facilitate fish passage (Evans and Johnston 1980). Low flow conditions must be thoroughly considered to avoid elevating the culvert above the stream bed. Never fill beneath the culvert just to bring it up to grade.

Culverts should be firmly anchored and earth should be compacted at least halfway up the side of the pipe to prevent water leaking around it. A minimum of half the culvert diameter (but not less than one foot) of fill should be placed above the culvert (Figure 45). Both ends of the culvert should protrude at least one foot beyond the fill.

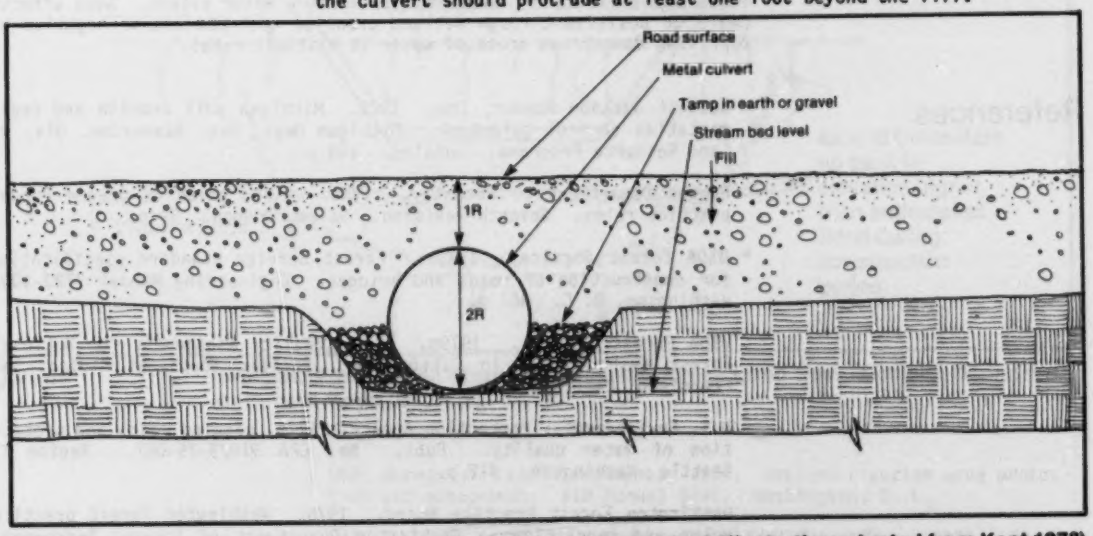

Figure 45 Culvert installation in streambed (Illustration adapted from Kent 1978).

Performance

Provided that other aspects of culvert design and placement are followed, this BMP should be highly effective in minimizing disruptions of the hydrological regime. Stoeckler (1967) found that improper culvert installation was the leading cause of timber damage in 70 wetland crossings in Minnesota. It is recommended in all or part by the states of Maine and Georgia and by the USDA Forest Service.

Limitations

If the bottom of a culvert is set too deeply in the substrate, the culvert may be more susceptible to clogging and a small area of stream bottom upstream may be eroded.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D. C. 63 p. and App. A-F.

Hewlett, J.D., W.P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia and USDA Soil Conservation Service. Athens. 25 p.

* Kent, B. 1978. Erosion control on logging jobs. The Land Use Handbook, Section 6. Maine Dept. Cons., Land Use Regulation Comm. Augusta. 28 p.

* Stoeckler, J.H. 1965. Drainage along swamp forest roads - lessons from northern Europe. J. Forestry 63:772-776.

* Stoeckler, J.H. 1967. Wetland road crossings: drainage problems and timber damage. USDA Forest Service Research Note NC-27. North Central Forest Exp. Stn., St. Paul, Minn.

USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. Number 7. California Region. San Francisco. 13 p.

*cited in text

5.9 Placement of Excavated Material

Purpose

To avoid sediment damage to streams and wetlands.

Description

Fill material should be confined within the roadway limits (Figure 46), as determined through design standards (BMP 3.1, Figure 8) set for the road.

Figure 46 **Fill material being kept within the roadway limits (Photo courtesy of the USDA Forest Service).**

Performance

This BMP is very important because the intentional or unintentional sidecasting or placing of fill in aquatic situations is almost certain to significantly alter the aquatic community. This BMP is recommended by the USDA Forest Service (1979).

Limitations

If the amount of excavated material is great, environmentally sound disposal areas (BMP 2.6) might be needed for placement of excavated material.

References

* USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720-100. Washington, D. C. 461 p.

*cited in text

5.0 Construction Operations

5.10 Excavation for Structures

Purpose

To reduce the probability of slope failure and consequent erosion during construction.

Description

Excavations for bridge abutments and related structures greater than 4 feet deep should have side slopes of 1.5:1 to 1 or flatter, depending on site conditions (solid rock not included). If hazardous ground movement can be expected (e.g., near most wetlands and streams), excavations under 4 feet should also be protected from slope failure.

Performance

This BMP should be effective in curbing sediment from slope failures, provided the slope is not left exposed for a long period of time. It is recommended by USDA Forest Service (1979).

References

* USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720-100. Washington, D. C. 461 p.

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*cited in text

Channel Clearance 5.11

Purposes

a) Remove barriers to fish movement.

b) Prevent clogging of stream crossing structures.

c) Avoid flow changes caused by debris jams.

Description

Debris that is accidently deposited in streams during the course of road construction (Figure 47) should be removed before work is terminated. Debris located within 50 feet upstream of a culvert that could reasonably be expected to drift downstream and clog the culvert also should be removed (Washington Forest Practice Board 1976). Finally, debris jams which obviously interfere with fish passage should be removed (Evans and Johnston 1980).

Figure 47 **Tree tops and other logging slash left in streams plug the channel and cause streambank erosion. Keep tops and slash out of streams or remove it before leaving the area (Photo courtesy of the Indiana Division of Forestry).**

In spite of their appearance, most log debris jams are not serious fish passage barriers (Evans and Johnston 1980); therefore, fish passage is not effective justification for removal of all material within streams. However, a definite barrier is created if the stream bed gradient has been raised several feet by gravel and rubble filling behind a jam. If removal is contemplated for these situations, it may be better to clear the channel of the constriction that originally caused the debris to collect.

Performance

During this process, all activities within the stream channel should be accomplished by hand to avoid the use of machinery within the stream and the riparian zone.

This BMP has historically received widespread support from fisheries biologists (White and Brynildson 1967), and is accepted by the U.S. Environmental Protection Agency (1975), the USDA Forest Service (1979), and several states including Washington (Washington Forest Practices Board 1976), Indiana (Owen and Lyons 1980), Georgia (Hewlett et al. 1979), Oregon (Oregon Department of Forestry 1980), and Michigan (Michigan Department of Natural Resources 1974). Barriers to fish migration would be reduced. Downstream from the activity, instream flows would be maintained especially during critical low water periods. Changes in riparian or wetland habitat would be minimized.

However, recent evidence suggests that this BMP may have resulted in the overcleaning of some streams. Marzoff (1980) suggested that excessive clearing and snagging of streams may reduce the channel's stability, decrease stream shading, decrease substrate diversity, introduce suspended solids, wash out accumulated gravels important to salmonid spawning, reduce wetland vegetation, and increase dissolved oxygen problems downstream. In Washington, it was found that slash was not a key factor in sluice outs (debris torrents) except at culvert sites. In fact, slash in meandering streams actually reduces the magnitude of sluice outs (Washington State Forest Practice Technical Advisory Committee 1979). However, Sachet et al. (1980) found this to be an appropriate BMP in Washington.

Limitations

Only human-caused slash (Thomas 1979) and obvious fish passage barriers (Evans and Johnston 1980) should be removed. Where cover is a limiting factor for fisheries or where slash actually helps stabilize the stream, this BMP may not be appropriate. Finally, unless specific guidelines are available, it could easily require a fisheries biologist to identify those debris jams which could cause a problem.

In the Pacific Northwest, 1976 costs for stream cleaning by hand ranged from $100-$500 per 100 feet of stream. Dykstra and Froelich (1976) proposed a rule of thumb as $60/ton/100 ft. of stream.

Bilby, R.E. and G.E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61(5):1107-1113.

* Dykstra, D.P. and H.A. Froelich. 1976. Costs of stream protection during timber harvest. J. Forestry 74(10):684-687.

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-12. Washington, D. C. 63 p. and App. A-F.

Froelich, H.A. 1973. Natural and man-caused slash in headwater streams. Loggers Handbook, Volume XXXIII. Pacific Logging Congress. XXXIII. 8 p.

* Hewlett, J.D., W.P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia. Athens. 25 p.

* Marzoff, G.R. 1980. The potential effects of clearing and snagging on stream ecosystems. USDI Fish Wildl. Serv. Publ. No. FWS/OBS-78/14. Office of Biological Services. Washington, D.C. 32 p.

* Michigan Department of Natural Resources. 1974. Rules and regulations concerning Inland Lakes and Streams Act. Hydrological Survey Division. East Lansing. 12 p.

* Oregon Department of Forestry. 1980. Field guide to Oregon forest practice rules. Seventh Revision. Salem, Oregon. 59 p.

* Owen, L.J. and T.M. Lyons. 1980. Logging roads and skid trails; a guide for soil protection and timber access. Indiana Dept. Nat. Res., Div. For., Indianapolis. 21 p.

* Sachet, J., S. Keller, A. McCoy, T. Orr, Jr., and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practice regulations in protecting water quality. Washington Dept. Ecol. Rept. No. DOE 80-7. Olympia. 76 p.

Swanson, F.J. and G. W. Lienkaemper. 1977. Physical consequences of large organic debris in northwest streams. Second Debris in Streams Workshop. Oregon St. Univ. Corvallis, OR.

* Thomas, J.W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service, Agric. Handbook 553. Washington, D.C. 512 p.

* USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Board. 1976. Washington Department of Natural Resources, Div. of Private Forestry Assistance and Regulations. Olympia. 54 p.

* Washington State Forest Practices Technical Advisory Committee. 1979. Forest practice demonstration project: Logging slash and debris. Washington Dept. of Ecology Report 79-5a-4. 38 p.

* White, R.J. and O.M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Wisconsin Dept. Nat. Res., Tech. Bull. 39. Madison. 64 p.

*cited in text

5.12 Full Bench/End Haul Construction Methods

Purpose

Prevent mass wasting and excessive erosion of fill in sensitive and unstable areas, and thus reduce turbidity and sedimentation concerns associated with aquatic biota.

Description

Use of full bench or end haul construction techniques should be required where significant amounts of fill material would rest where they would reasonably be expected to eventually erode into high quality waters if sidecast construction practices were used, or if roads are located in unstable soils and slope areas (Washington Forest Practice Board 1976).

Full bench/end haul techniques involve cutting the entire width of the road from the side of the hill (Figure 48). No fill material from the cut is used to widen the road and excess material would be hauled to an appropriate disposal area. Sidecast construction techniques include cutting only part of the road's width from the slope with the remaining width built from the fill generated in the cut (Figure 49).

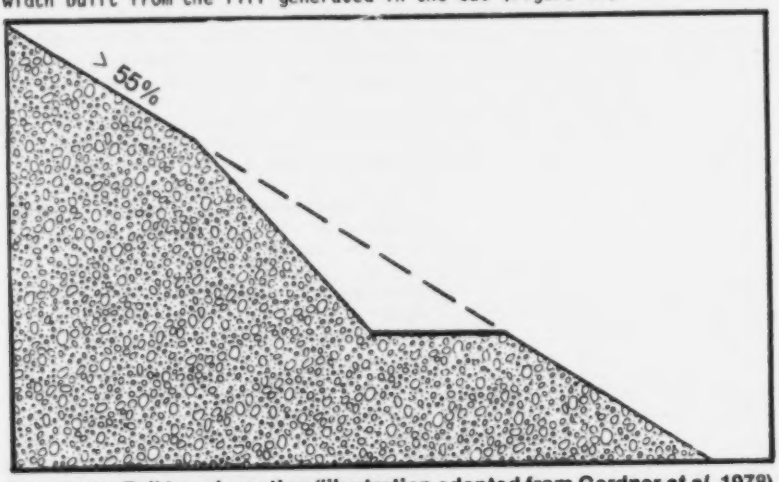

Figure 48 Full bench section (illustration adapted from Gardner *et al.* 1978).

Performance

Gardner et al. (1978) observed that forest road stability in Idaho was obtained if full bench construction were used on slopes greater than 55 percent. Such a design eliminates bare fill slopes which are prone to erosion. However, it increases the amount of material which must be disposed. Where regulations prohibit the use of sidecast techniques where fill material would rest below the 25-year floodplain of high quality waters, Sachet et al. (1980) felt the use of full bench/end haul techniques to be useful to the protection of water values.

Limitations

This BMP is only needed in areas of steep topography and/or unstable soils where it is difficult to stabilize fills. Gentle sloped areas where fills can be rapidly stabilized with vegetation do not require this BMP.

Full Bench/End Haul Construction Methods 5.12

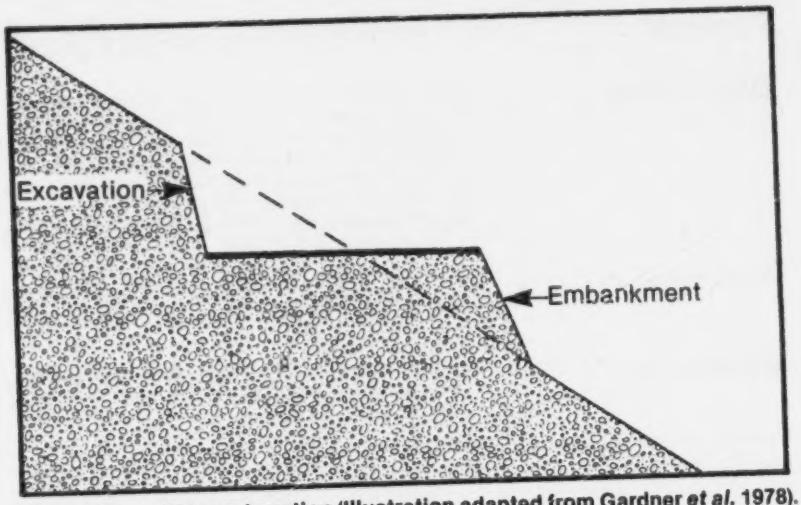

Figure 49 **Sidecast section (Illustration adapted from Gardner *et al.* 1978).**

End haul construction methods would increase costs over sidecast methods. The increase would be variable, but would be strongly related to the distance needed to transport spoil materials.

References

* Gardner, R.B., W.S. Hartsog, and K.B. Dye. 1978. Road design guidelines for the Idaho batholith based on the China Glenn Road study. USDA Forest Service Res. Paper INT-204. Intermountain Forest and Range Exp. Stn. Ogden, Utah. 20 p.

* Sachet, J., S. Keller, A. McCoy, T. Orr, Jr., and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practices regulations in protecting water quality. Rept. No. DOE 80-7. Washington Dept. Ecol. Olympia. 76 p.

USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. Number 7. California Region. San Francisco. 13 p.

USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Department of Natural Resources, Division of Private Forestry Assistance and Regulations. Olympia. 54 p.

*cited in text

5.13 Construction Area Drainage

Purpose

To keep hazardous substances out of streams and wetlands.

Description

Construction area drainage should be collected and kept from streams. Seepage pits or other confinement measures should be used and maintained to prevent diesel oil, fuel oil, or other liquids from running into stream (Figure 50) or important aquifers. Drip collectors should be used on oil-transporting vehicles. Water for sprinkler trucks should be diverted a sufficient distance from the source to the filling point to prevent overflow spilling or flushed tank water from reaching the stream.

Performance

This BMP should be effective if compliance is complete. It is recommended by EPA (USDI Federal Water Pollution Control Administration 1970).

References

* USDI Federal W[illegible] Pollution Control Administration. 1970. Industrial waste guide; lo[illegible]ng practices. Northwest Region. Portland, Oregon. 40 p. and 37 Figures.

Figure 50 **A natural settling basin settled out this silt from a roadside ditch before it reached the trout stream in the background. Use of settling basins is important in trout management and in protecting water quality (Photo courtesy of the USDA Forest Service).**

*cited in text

Water Supply Points 5.14

Purpose

To prevent excessively low water levels, reduce stream bank erosion, and minimize sedimentation.

Description

Water supply points, for use in dust reduction (sprinkling), batch mixing, or other exploitive purposes should be specified beforehand and reviewed from a perspective of potential damage to fisheries. Causes for concern include aquatic organism entrainment, scouring of spawning areas, reduced groundwater levels or other undesirable alterations. Water withdrawal structures should not be prone to leaking, and any damage from water gathering should be repaired. If cofferdams or waterholes are constructed of sandbags, they should be filled with sand or gravel that is clean. At no time should downstream water flow be reduced to a level detrimental to aquatic resources.

Performance

This BMP should be effective if compliance is complete. It is recommended by USDA Forest Service (1979).

References

USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. Number 7. California Region. San Francisco. 13 p.

* USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

*cited in text

5.15 Borrow and Disposal Drainage

Purpose

To reduce transport of sediments from borrow or disposal areas to nearby water bodies.

Description

Inorganic spoils should be used as road fills whenever the material meets engineering standards for the fill. To the extent that this is not possible, spoils should be placed such that water does not pond within the disposal area. Runoff water from spoil disposal areas should either be diverted onto the forest floor or be passed through one or more settling basins.

Performance

Gravel pits, quarries, and borrow pits are often major sources of sediment. Thus, compliance with BMPs such as this, will result in a slight to moderate reduction of damage to fisheries. Sedimentation basins may be significantly beneficial to aquatic wildlife for their occasional resemblance to natural wetlands.

This BMP is recommended by the State of Washington (Washington Forest Practice Board 1976) and by EPA (1975).

Limitations

Effectiveness of sediment basins is limited by the fact that they permit sedimentation of coarse particles only; silt and clay remain in suspension. Also, sedimentation basins require regular and long-term checking and maintenance. Sediment basins may be harmful to fisheries if (due to improper maintenance) they suddenly wash out and empty months of accumulated sediment into a water body. This BMP is most desirable and useful where disposal areas must be very near the floodplain and where soils are fairly coarse-grained.

References

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910-9-75-007. Region X. Seattle, Washington. 312 p.

* Washington Forest Practice Boards. 1976. Washington Department of Natural Resources, Division of Private Forestry Assistance and Regulations. Olympia. 54 p.

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*cited in text

Inspection 6.1

Purposes

a) Determine erosion and sedimentation problems.

b) Insure proper functioning of water crossing structures for flood protection.

c) Maintain conditions for fish passage.

Description

After the first rain in the wet season, roads should be checked to see if and where drainage problems have developed. During heavy runoff periods, road surfaces should be checked to see that drainage systems are functioning. Culverts should be inspected at least annually to insure they are functioning properly for fish passage. Where fish passage is a significant concern, inspection just before the migration season(s) would be appropriate. Moreover, checks during the migration season, especially after periods of high flows, would insure that fish passage would not be significantly affected by storms that cause debris to block water crossing structures.

Performance

This BMP has been written into several guidance documents for the Forest Service in California (Evans and Johnston 1980; USDA Forest Service 1973, 1979). It has not been widely accepted at the state level, possibly because of the existence of other BMPs which simply require fill stabilization and culvert cleaning to be accomplished on an "as needed" basis.

Limitations

For landowners with extensive road systems, this BMP could be costly, unless the roads involved are routinely driven.

While complete inspection of the entire road system could be beneficial and could be appropriate to a nonpoint source (208) program, only the sites of stream and wetland crossings would be applicable under a dredge and fill (404) program.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Serv. EM 7100-12. Washington, D.C. 63 p. + App. A-F.

* USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. Number 7. California Region. San Francisco.

* USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

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6.0 Maintenance

6.2 Culverts/Stream Crossing Structures

Purposes

a) Maintain drainage and flow.

b) Insure fish passage.

Description

Stream crossing structures and their inlets should be kept free of debris, slides, rocks, and other materials. Most of this activity can be accomplished by hand. It should be accomplished prior to and following any heavy runoff period.

Performance

This BMP was universally accepted by all state BMP documents reviewed, the Forest Service, and the Environmental Protection Agency. There was no desire noted to repeal this BMP.

References

Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd Edition. USDA Forest Service, State and Private Forestry. Northeastern Area. Broomall, Pa. 43 p.

Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. USDA Forest Serv., Res. Paper NE-158. NE Forest Exp. Stn., Upper Darby, Pa. 28 p., illus.

Michigan Department of Natural Resources. 1977. Forest best management practices program for water quality in Michigan. East Lansing. 9 p.

Singer, J.R. and R.C. Maloney. 1977. Nonpoint source control guidance; silviculture. U.S. Environmental Protection Agency, Office of Water Planning and Standards. Washington, D.C.

U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. California Region. San Francisco. 13 p.

USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. EM 7720-100. Washington, D.C. 461 p.

USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco.

Fill Slopes 6.3

Purpose

Reduce erosion and sedimentation problems.

Description

Fill slopes should be maintained so that developing erosion areas are treated and stabilized. The U.S. Environmental Protection Agency (1975) indicated that due to the individuality of slopes, no one or two methods could be universally recommended. However, the authors described one method that had worked in instances where erosion was not too far advanced. The procedure involved filling the erosion clefts with porous material, such as gravel or rocks, and establishing vegetation through sodding.

Performance

This BMP is generally not recommended by state agencies or Federal land managing agencies. However, all agencies do agree that slopes must receive proper stabilization (Chapter 4.0).

Repair of fill slopes has met with mixed success. In many cases it was accomplished effectively, while in others, repair was difficult. Obviously, it is better to effectively stabilize fill slopes during or just after construction rather than to continually stabilize them.

Limitations

Soils, slopes of the fill slope, and climate will all affect the degree to which fill slope maintenance will be accomplished. Poor soil and steep slopes would probably increase reliance on structures (e.g., bulkheads, retaining walls) rather than vegetation for fill stabilization. The type of vegetation established will also depend on these variables.

References

* U.S. Environmental Protection Agency. 1975. Logging roads and the protection of water quality. Publ. No. EPA 910/9-74-007. Region X. Seattle, Washington. 312 p.

*cited in text

6.0 Maintenance

6.4 Protection of Wooden Stream Crossings

Purpose

To insure integrity and reduce maintenance of wooden bridges.

Description

During road grading operations, wooden bridges should be covered with poles or slabs prior to crossing with bulldozers or graders.

Performance

This BMP was included in Federal agency direction for the Forest Service (Kochenderfer 1970) and the U.S. Environmental Protection Agency (1975). It has not been adopted in any state programs. It would seem that this BMP would be in the operator's best interests since it would reduce overall maintenance costs. It would have a slightly beneficial effect on fish and wildlife resources by reducing the potential for bridge failures.

References

* Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. USDA Forest Service Res. Paper NE-158. NE Forest Exp. Stn., Upper Darby, Pa. 28 p.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

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*cited in text

Restoration to Natural Conditions 7.0

Removal of Culverts and Bridges 7.1

Purposes

a) Protect stream crossings from erosion.

b) Maintain adequate drainage.

Description

Upon completion of active use, temporary water crossings should be removed (Figure 51). At the same time, approaches to the stream crossing should have waterbars constructed (Figures 52, 53; Table 9) and be stabilized with the use of vegetation (BMP 4.4).

For permanent roads that have been abandoned, water crossings should be removed if maintenance is to be discontinued. However, bridge abutments should be left in place if they protect the streambank from erosion.

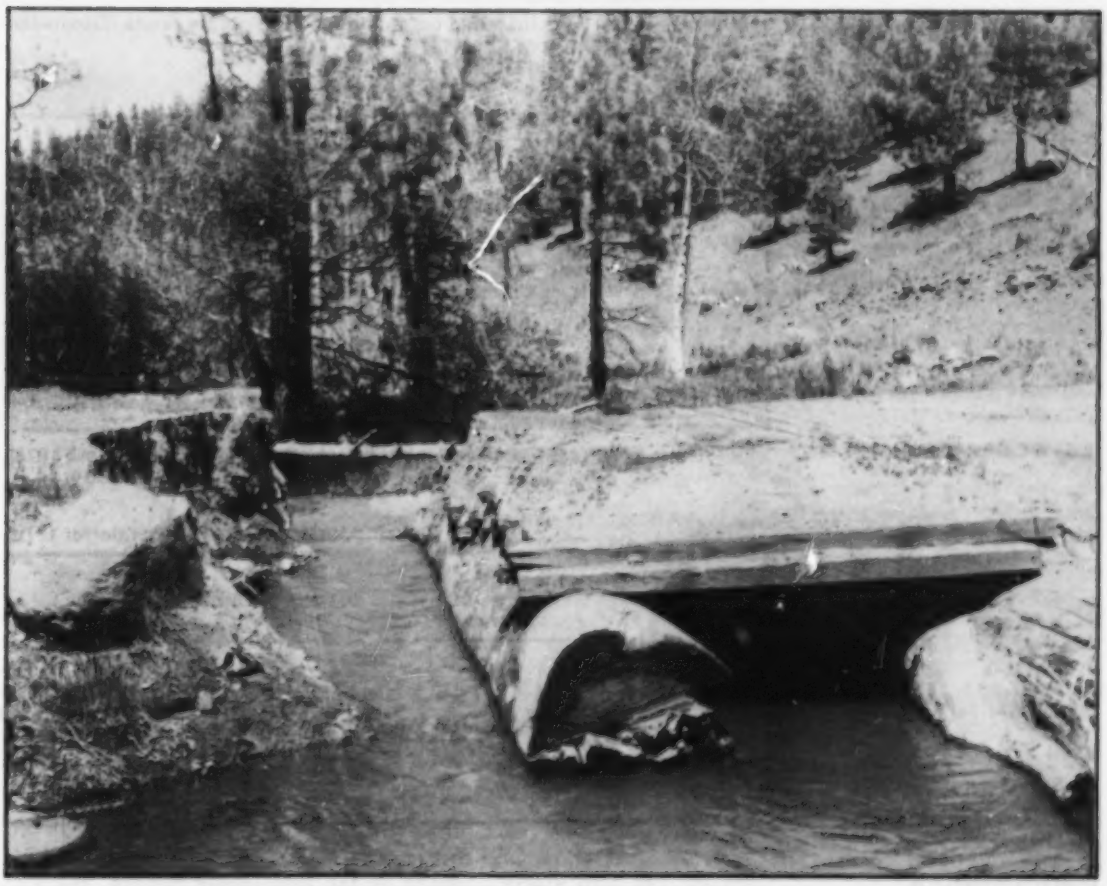

Figure 51 **If not removed following use, temporary crossing structures can cause significant damage. This failure of a temporary log culvert greatly increased sedimentation and turbidity in the stream (Photo courtesy of the USDA Forest Service).**

Figure 52 Water bars installed on abandoned temporary roads (Illustration adapted from Kent 1978).

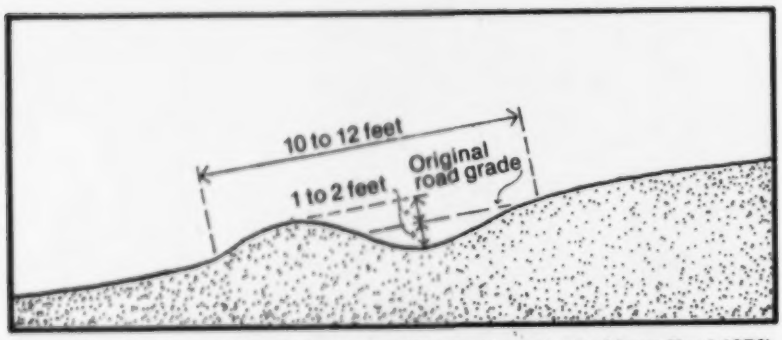

Figure 53 Cross section of water bar (Illustration adapted from Kent 1978).

Table 9. Spacing for waterbars (Kochenderfer 1970).

Road grade (percent)	Distance between waterbars (feet)
2	250
5	135
10	80
15	60
20	45
25	40
30	35

Performance

This BMP has been widely accepted by the USDA Forest Service, the U.S. Environmental Protection Agency, as well as the states of Washington, North Carolina, Indiana, West Virginia, and Michigan. Generally, this BMP will protect from future fill erosion and from future unwanted damming of water bodies.

Removal of Culverts and Bridges 7.1

Limitations

There has been some recent thought given to the adverse effects due to erosion and sedimentation which result from activities in the water conducted under the auspices of restoration and from improper stabilization after restoration (U.S. Environmental Protection Agency 1975; Kochenderfer, personal communication, USDA Forest Service, Northeastern Forest Exper. Stn., Parsons, West Va.). This has resulted in the Environmental Protection Agency (1975) recommending removal of only those crossing structures which have a high risk of fill failure or debris blockage. However, there has been very little effort to distinguish between "high risk" and "low risk" structures.

References

Haussman, R.F. and E.W. Pruett. 1978. Permanent logging roads for better woodlot management. 3rd. Edition. USDA Forest Service, State and Private Forestry. Northeastern Area. Broomall, Pa. 43 p.

Kent, B. 1978. Erosion control on logging jobs. The Land Use Handbook, Section 6. Maine Dept. Cons., Land Use Reg. Comm., Augusta. 28 p.

Michigan Department of Natural Resources. 1977. Forest best management practices program for water quality in Michigan. East Lansing. 9 p.

Owen, L.J. and T.M. Lyons. 1970. Logging roads and skid trails; a guide for soil protection and timber access. Indiana Dept. Nat. Res., Div. For., Indianapolis. 21 p.

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

USDA Forest Service. 1979. Forest Service standard specifications for construction of roads and bridges. Engineering Manual 7720-100. Washington, D.C. 461 p.

USDA Forest Service. 1979. Obliteration of roads. FSM 7713.6. Region 2 Supplement 35. Denver, Colorado.

USDA Forest Service. 1979. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

*cited in text

7.0 Restoration to Natural Conditions

7.2 Borrow Pits and Disposal Areas

Purposes

a) Reduce erosion, sedimentation, and turbidity problems from abandoned borrow and disposal areas.

b) Provide a timber and/or wildlife value to the abandoned areas.

Description

All borrow areas should be reclaimed as soon as possible following abandonment (Figure 54). All deleterious material which would damage the public resource, adversely affect soil productivity, or interfere with revegetation should be removed. Slopes should be graded to less than the angle of repose and revegetated with the appropriate woody, herbaceous, or grass species (BMP 4.4). In Washington, a maximum period of 2 years is allotted for complete reclamation including revegetation (Washington Forest Practice Board 1976).

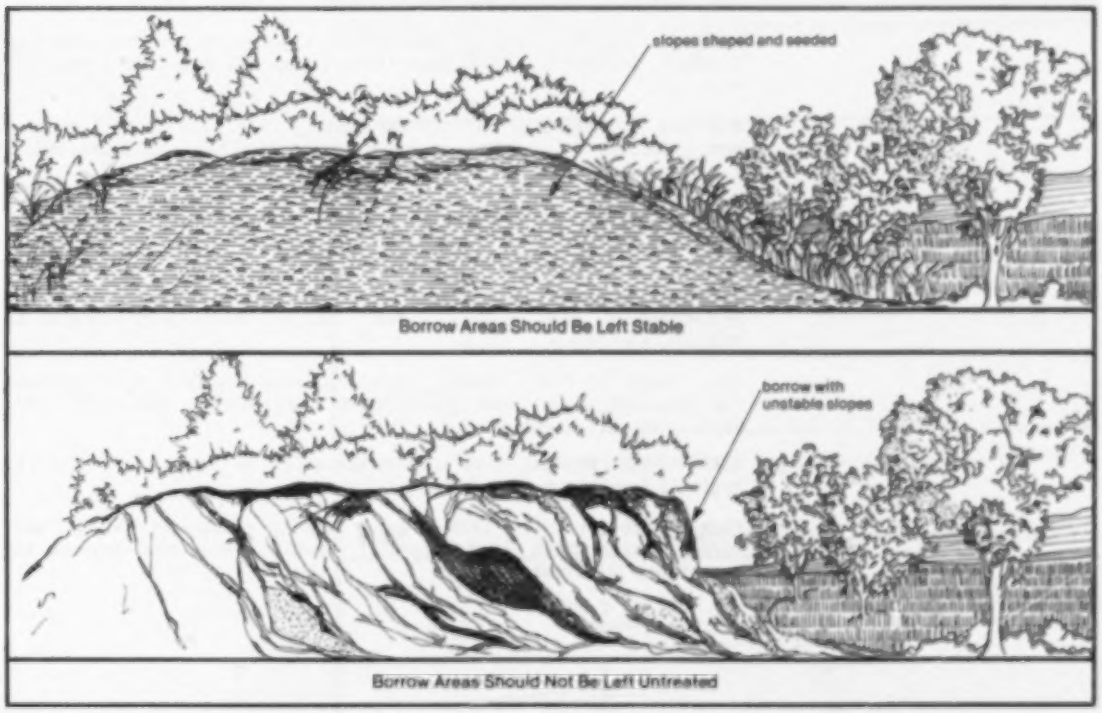

Figure 54 **Reclamation of borrow areas (illustration adapted from Beckett Jackson Raeder, Inc. 1979).**

Disposal areas (Figure 55) should also be revegetated in the most appropriate fashion as described in BMP 4.4. If erosion occurs, waterbars and/or mulching should be used to augment erosion control.

Performance

This BMP is accepted by Washington (Washington Forest Practice Board 1976), Oregon (Oregon Department of Forestry 1980), Michigan (Beckett Jackson Raeder, Inc. 1979), and the USDA Forest Service (1979a; 1979b).

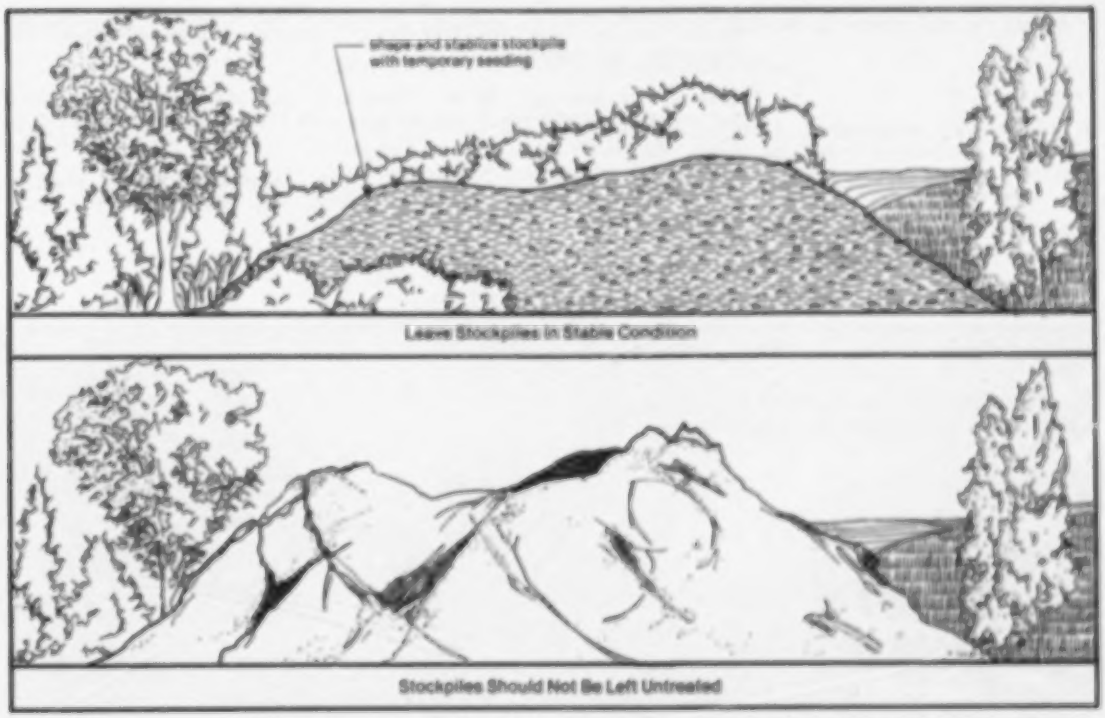

Figure 55 **Reclamation of disposal areas (Illustration adapted from Beckett Jackson Raeder, Inc. 1979).**

A recent assessment of Washington's regulations revealed no need to modify this BMP (Sachet et al. 1980).

Limitations

In some areas, particularly flatter, low lying regions such as the Mississippi River Valley or the area around the Great Lakes, borrow pits frequently, and naturally fill with water and form wetlands, lakes, and ponds (Figure 56). Valuable fish and wildlife habitat is often the result in these instances.

References

* Beckett Jackson Raeder, Inc. 1979. Michigan soil erosion and sedimentation control guidebook. Michigan Dept. Nat. Res., Div. of Land Res. Programs. Lansing. 108 p.

* Oregon Department of Forestry. 1980. Field guide to Oregon forest practice rules. Seventh Revision. Salem, Oregon. 59 p.

* Sachet, J., S. Keller, A. McCoy, T. Orr, Jr., and N. Wolff. 1980. An assessment of the adequacy of Washington's forest practice regulations in protecting water quality. Washington Dept. Ecol. Rept. No. DOE 80-7. Olympia. 76 p.

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* USDA Forest Service. 1979a. Water quality management for National Forest System lands in California. Pacific Southwest Region. San Francisco, California.

* USDA Forest Service. 1979b. Forest Service standard specifications for construction of roads and bridges. EM 7720-100. Washington, D.C. 461 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. Priv. For. Assist. and Regs. Olympia. 54 p.

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*cited in text

Figure 56 **This borrow area is being slowly filled by surface runoff. The wetland's value to wildlife is evident by a high degree of use by big game and other wildlife (Photo by J.R. Hynson).**

Timing 7.3

Purposes

a) To complete activities prior to periods of severe erosion hazard.

b) To avoid critical fish spawning periods.

Description

Where distinct wet and dry seasons exist, restoration work should be completed before the first wet season following termination of active use (Washington Forest Practice Board 1976). In other areas, efforts should be made as soon as possible after termination of active use.

Temporary stream crossing structures should be removed prior to spawning seasons (Table 10) of important fish resources (Evans and Johnston 1980). This is less critical for bridges than for other crossing structures, because bridges have less potential to block and create barriers than do culverts.

Table 10. Spawning migration periods for important fish species in California (Evans and Johnston 1980).

Species	Period of Spawning Runs
Anadromous Fishes	October 1 - April 30
Silver Salmon	October 1 - January 30
King Salmon--Fall Run	October 1 - December 31
King Salmon--Fall Run	April 1 - June 30
Steelhead	October 1 - April 30
Resident Trout (Spring Spawn)	April 1 - July 30 (depends on elevation)
Resident Trout and Kokanee (Fall Spawn)	September 1 - November 30 (depends on elevation)

Performance

Timing to avoid critical periods is effective in reducing erosion and in minimizing problems to fish passage. If restoration work is completed in a timely manner, vegetation and other erosion control measures are operating prior to significant erosion periods. Removal of stream crossing structures in a timely manner insures that stream will not be blocked during the periods when fish migration is most critical.

Limitations

If the specific water involved serves as significant fishery habitat during low water, activities should be rescheduled slightly to avoid this period.

References

* Evans, W.A. and B. Johnston. 1980. Fish migration and fish passage; a practical guide to solving fish passage problems. USDA Forest Service EM 7100-2. Washington, D.C. 63 p. + App. A-F.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. Nat. Res., Div. of Private For. Assist. and Regs. Olympia. 54 p.

*cited in text

7.4 Inspections of Closed Roads

Purposes

a) Insure vegetational stabilization measures are operating as planned.

b) Insure drainage structures are operational.

Description

This BMP involves periodic visual inspections of closed roads. The inspection should be accomplished annually for the first two years following abandonment. At these times, seeded and planted sections should be observed to insure that vegetation is successfully adapting to the site. Drainage structures should be examined to see if they were performing as planned. Maintenance should be conducted on an "as needed" basis.

Performance

Only New Hampshire (Winkelaar 1971) and the U.S. Environmental Protection Agency (1975) have explicitly adopted this BMP. However, BMPs which require effective stabilization for closed roads imply its use. No data indicate whether or not it is needed or useful. However, by possibly reducing turbidity, sedimentation, and shoreline erosion problems, fish and wildlife could benefit greatly.

Limitations

This BMP would be especially limited for landowners who have extensive amounts of closed roads and limited time for inspections. Costs would be major factors for such groups.

References

* U.S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

* Winkelaar, P. 1971. Forest road location and erosion control on northern New Hampshire soils. Coop. Ext. Serv., Univ. New Hampshire. Durham. 18 p.

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*cited in text

Appendix A

Research Methods Used in Analysis

Two basic steps were used to complete the necessary research for this report: BMP identification and evaluation of potential BMPs. The entire process was repeated twice. Initially, BMPs which have current institutional standing were identified and evaluated. These were derived from Federal and State agency manuals, as well as existing State regulatory and voluntary BMP programs. Following analysis of each initially identified BMP, the entire system was assessed to insure that all fish and wildlife impacts and all Consolidated Permit Regulations were addressed. A need for new BMPs was identified for those fish and wildlife impacts and Consolidated Permit Regulations which were not addressed. A second set of potential BMPs was then identified from the scientific literature. Once the new BMPs were identified, they too were subjected to the evaluation process.

BMP Identification

Description. Initially, BMPs were extracted from the following sources:

Various handbooks, manual sections, standard specifications, and Regional Supplements and other guidance from the USDA Forest Service.

Selected guidance documents from the U.S. Environmental Protection Agency.

Relevant sections of the USDA Soil Conservation Service Technical Guide for the states of Michigan, Colorado, and California.

Selected manual sections of the USDI Bureau of Land Management.

Voluntary BMP programs developed for the States of Florida, North Carolina, Indiana, West Virginia, Virginia, Maine, and Georgia.

Rules and regulations mandated by legislation for the State of Michigan, Oregon, and Washington.

Relevant information for each BMP was summarized on a standard form (Figure 57). This information included title, institutional status, purposes, description and applicable references. Each BMP was numbered and cross referenced to other potential BMPs.

Prior to the formal evaluation, the applicability of the BMP to the scope of the study was determined. To meet this qualification, the BMP had to be:

a) Specific to activities in waters and adjacent wetlands; and

b) Applicable to dredge and fill discharges associated with farm or forest road construction and maintenance.

Several BMPs that met the above criteria were also applicable to activities that were outside the scope of the document. Two examples of this situation included general design standards for roads that are used in both upland and wetland locations and road surface water drainage structures which are also used in both upland and wetland situations. In these instances, BMPs were generally modified to include only those uses applicable to this study. When modification was not possible, the fact that the BMP was limited by its applicability to a dredge and fill program was noted as a "Limitation" in the text.

Example. One completed BMP identification form (Figure 57) is presented to further explain this process. This BMP (2.5) consists of a variety of site criteria for stream crossings. At the top of the form is a BMP number and a title. The BMP number references the most appropriate chapter of the text to place the BMP (in this case, 2 for Route and Facility Location Planning), and a second individual number (5) to separate this BMP from all others that could be placed in Chapter 2.0. For organizational clarity, BMPs were reorganized and renumbered for the Handbook once the entire list of accepted BMPs was complete.

Directly under the BMP number and title is a list of other BMPs which are similar. Similarity between BMPs was based on titles as shown on the form. A second BMP could be similar if it contained elements which augmented the ones provided in this BMP or if it contained statements that

BMP Identification Form

BMP Number: 2-5 Stream Crossings

Number of similar BMP(s) 2-33, 2-19-, 2-26, 2-25

Status: (check one)
Existing or proposed

(check those applicable)
Identified through 208 plan
List state(s)/area(s)

WA, IN, GA, FL, NC, WV, OR

Agency directive
List agency(ies)

Forest Service (NE Area) FS (R-5)

Purpose: Minimize erosion, sedimentation, and habitat loss

Description: Most state stream crossings should be avoided where possible. Cross stream perpendicular rather than at angle. Alignment of stream and road should be straight in all four directions. The stream bed should be straight and of uniform profile for unobstructed water flow. If bridge is used, grade should coincide with that of rest of road. Avoid deeply cut stream channels and soft, muddy soil. Choose narrow place with relatively low banks and firm rocky soil. To be used if culverts are necessary: (1) No sudden increase in gradient or water velocity for at least 100 ft. above, below, or at the crossing location. (2) Channel gradient should be as near zero as possible. (3) Stream channel should have similar alignment for at least 100 ft. above and below culvert entrance and exit.

Reference(s)
(give complete citation)

Haussman, R. F. & E. W. Pruett. 1978. Permanent logging roads for better wood lot management. 3rd edition. USDA Forest Service, State and Private Forestry, Northeastern Area. 43 p. Broomall, PA.

Kochenderfer, J. H. 1970. Erosion control on logging roads in the Appalachians. USDA Forest Serv. Res. Paper NE-158. NE Forest Exper. Stn., Upper Darby, PA. 28 p.

Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Washington Dept. of Natural Resources, Div. of Private Forestry Assistance and Regulations. Olympia. 54 p.

Owen L. J. & T. M. Lyons. 1980. Logging roads and skid trails; a guide for soil protection and timber access. Indiana Dept. Nat. Resources, Div. of Forestry. Indianapolis. 21 p.

Hewlett, J. D., W. P. Thompson, and N. Brightwell. 1979. Erosion control on forest land in Georgia. Univ. Georgia and USDA Soil Conservation Service. Athens. 25 p.

Kent, B. 1978. Erosion control on logging jobs. The Land Use Handbook, Section 6. Maine Dept. of Cons., Land Use Regulation Comm. Augusta. 28 p.

Florida Div. of Forestry. Silviculture best management practice manual. Dept. Ag. and Consumer Serv. Tallahassee.

USDA Forest Service. 1973. Protecting fish habitat during forest road development. Coordination guidelines for fish and wildlife habitats. Number 7. California Region. San Francisco. 13 p.

Winkellar, P. 1971. Forest road location and erosion control on northern New Hampshire soils. Coop. Ext. Serv., U. New Hampshire. Durham. 19 p.

Kelly, A. W. & Committee. n. d. Silviculture water quality management plan. West Va. Dept. Nat. Res., 208 Silvicultural Tech. Action Comm. Charleston. 50 p. + 5 Exhibits.

U. S. Environmental Protection Agency. 1975. Logging roads and protection of water quality. Publ. No. EPA 910/9-75-007. Region X. Seattle, Washington. 312 p.

Oregon Department of Forestry. 1980. Field guide to Oregon forest practice rules. Seventh Revision. Salem, Oregon. 59 p.

Figure 57 **Sample completed BMP Identification Form.**

directly contradicted the ones given in the initial BMP. If similar BMPs augmented the initial BMP, they were later evaluated for possible inclusion into a single, comprehensive description. If similar BMPs contradicted the initial BMP, they were considered as alternatives during the evaluation process.

Status determination was the next step in the process. Using a characterization of the documents that originally stated the BMP, practices that had institutional standing were separated from ones that did not. In this case, the BMP was found in the rules and regulations, as well as in voluntary BMP programs of several States. Thus, it was considered as "existing or proposed" because it had institutional recognition. It was evaluated as an initial BMP. If it had only been found in scientific papers, it would be considered "research" and would have been evaluated with the second group of BMPs.

The next spaces of the identification form consist of "Purpose" and "Description". Both were summarized from the documents that initially stated the BMP. The "Purpose" section attempted to state what environmental impacts were reduced in such a fashion as to enable rapid cross-referencing with the baseline provisions of the Consolidated Permit Regulations (40 CFR 123.92(a)(6)). The "Description" was a summary of directions of how to implement the BMP. If the BMP were accepted during the evaluation process, these sections were used as the basis for the analagous sections in the text of the Handbook.

Finally, all references that described the BMP were listed in their entirety, according to AIBS format. These also were later incorporated into the text of the BMP if it were accepted.

Evaluation

Description. A standard format modified from that developed by Shuldiner et al. (1979) (Figure 58) was used by an interdisciplinary team to evaluate each BMP. The evaluation involved ranking environmental effects with and without the BMP, determination of applicability to Consolidated Permit Regulations (40 CFR 123.92(a)(6)), identification of limitations, acceptability determination, and development of modifications to resolve possible concerns created by the BMP.

The team's physical scientist (expertise in civil engineering, soils, and hydrology) initiated evaluation of environmental impacts. Based upon the information contained in the "Description" section of the identification form, the BMP was divided as necessary into components that aided that individual in analysis. These components were arranged in a flow chart on the left hand side of the impact matrix. The physical impacts of each component were identified by drawing arrows to relevant impacts listed vertically on the evaluation matrix. Each arrow indicated both the magnitude of the impact and whether or not the BMP increased or decreased its effect.

Biological scientists then assessed each biological effect associated with the relevant physical impacts by determining effect magnitude and direction without the BMP (upper left corner of each physical/biological impact association in the matrix) and with the BMP (lower right corner). In order to make these determinations, it was necessary to assume that all other relevant BMPs had been incorporated into the BMP system. For example, the analysis for design features of water crossings assumed that, in individual cases, the need for the crossing was appropriately determined, and the proper choice of location was made.

Concurrently with the impact assessment, each member of the team was asked to verbally define and describe the significance of limitations appropriate to their specialty. Types of limitations included cost, soils, slope, hydrology, climate, geology, wildlife, and aquatic ecology, as listed on item 3.0 of the evaluation form. Both the impacts and limitations were used to determine which of the Consolidated Permit Regulations were addressed by the BMP, and which could be violated (Item 2.0 on the evaluation form). If concerns were evident from the analysis, modifications to the BMP were suggested by appropriate members of the project team and evaluated along with the BMP.

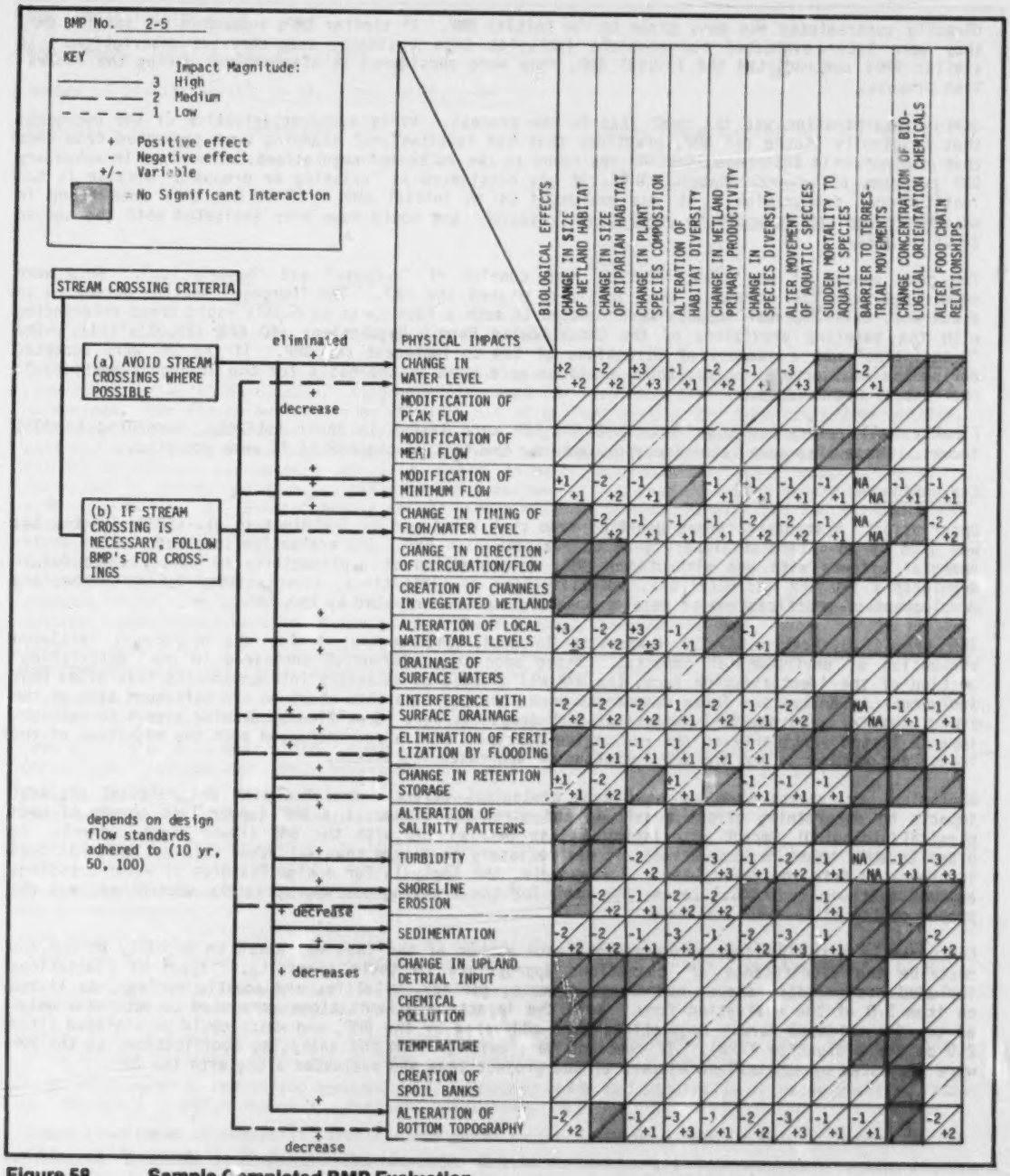

Figure 58 **Sample Completed BMP Evaluation.**

Research Methods Used in Analysis

BMP EVALUATION FORM

2.0 Consolidated Permit Regulations (check those which are applicable to this BMP).

(i). Permanent roads (for farming or forestry activities), temporary access roads (for mining, forestry, or farm purposes), and skid trails (for logging) in waters of the U.S. shall be held to the minimum feasible number, width, and total length consistent with the purpose of specific farming, silvicultural or mining operations, and local topographic and climatic conditions;

(ii) All roads, temporary or permanent, shall be located sufficiently far from stream or other water bodies (except for portions of such roads which must cross water bodies) to minimize discharges of dredged or fill material into waters of the U.S.;

(iii). The road fill shall be bridged, culverted, or otherwise designed to prevent the restriction of expected flood flows;

(iv). The fill shall be properly stabilized and maintained during and following construction to prevent erosion;

(v). Discharges of dredged or fill material into waters of the United States to construct a road fill shall be made in a manner that minimizes the encroachment of trucks, tractors, bulldozers, or other heavy equipment within waters of the United States (including adjacent wetlands) that lie outside the lateral boundaries of the fill itself;

(vi). In designing, constructing, and maintaining roads, vegetative disturbance in the waters of the United States shall be kept to a minimum;

(vii). The design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the water body;

(viii). Borrow material shall be taken from upland sources whenever feasible;

(ix). The discharge shall not take, or jeopardize the continued existence of, a threatened or endangered species as defined under the Endangered Species Act, or adversely modify or destroy the critical habitat of such species;

(x). Discharges into breeding and nesting areas for migratory waterfowl, spawning areas, and wetlands shall be avoided if practical alternatives exist;

(xi). The discharge shall not be located in the proximity of a public water supply intake,

(xii). The discharge shall not occur in areas of concentrated shellfish production;

(xiii). The discharge shall not occur in a component of the National Wild and Scenic River System;

(xiv). The discharge of material shall consist of suitable material free from toxic pollutants in toxic amounts; and

(xv). All temporary fills shall be removed in their entirety and the area restored to its original elevation.

3.0 Limitations

Cost- *Strict adherence to BMP will increase construction cost*

Slope- *There may be situations where these conditions cannot be met and rerouting could cause more severe impacts*

Hydrology-

Climate-

Geology-

Wildlife- *Only right place could cross significant wildlife area, but that's handled by another BMP.*

Aquatic ecology-

4.0 Determination (check one)

acceptable acceptable with modifications not acceptable

5.0 Discussion (present reasoning for a "not acceptable" rating, or description and rationale proposed modification for an "acceptable with modifications" rating).

Effectively reduces impacts

6.0 References if not listed on BMP Identification Form (give completed citation and description of how reference was used).

Figure 58 concluded.

All the information gained in the analysis was used to determine whether or not the BMP was acceptable for inclusion into the BMP system presented. The following criteria were used to make this determination:

Acceptable

(a) No adverse impact (upper left-hand corner of interaction boxes) of a magnitude of 2 or 3 which is not effectively ameliorated by the BMP (lower right-hand corner of the interaction boxes);

(b) At least one amelioration/mitigation effect (lower right-hand corner) of 3;

(c) A minimum of adverse impacts (upper left-hand corner) of magnitude of 1 that are not ameliorated (lower right-hand corner) when a variety of similar BMPs are being compared;

(d) Recognizable effect of the BMP in reducing adverse environmental impacts;

(e) Applicable to at least one baseline provision;

(f) No violation of baseline provisions; and

(g) No significant limitations that cannot be dealt with on a site specific basis.

Acceptable with modifications

(a) Unaltered BMP does not meet one or more of the "acceptable" criteria;

(b) Proposed modification successfully addresses the "acceptable" criteria not met by unaltered BMP; and

(c) Proposed modification does not violate any other "acceptable" criteria.

Not acceptable

(a) Unaltered BMP does not meet one or more of the "acceptable" criteria;

(b) No modifications exist; and/or

(c) Modifications do not successfully address "accceptable" criteria.

Example. The example of the stream crossing BMP (2.5) is continued to provide consistency. Based on review of the "Description" section of the identification form, two major components were identified. The first was avoidance of stream crossings wherever possible, while the second included all the site criteria specified when stream crossings were necessary.

Both components were found to decrease the following physical impacts from forest or farm road stream crossings:

Change in water level;
Modification of minimum flow;
Change in timing of flow/water level;
Alteration of local water table levels;
Interference with surface drainage;
Elimination of fertilization by flooding;
Change in retention storage;
Shoreline erosion;
Sedimentation;
Alteration of bottom topography.

In addition, avoidance of stream crossings was found to reduce turbidity, and to completely eliminate all physical impacts of stream crossings. The site criteria were found to reduce, but not eliminate impacts.

Biological evaluation showed that most, if not all ecological effects caused by interactions with physical impacts were reduced with implementation of this BMP. This is indicated by the prevalence of negative numbers in the upper left-hand corners of the appropriate biological/physical interation boxes and the majority of positive numbers in the lower right-hand corners. Thus, all biological effects were reduced, if not eliminated.

The project staff did find some limitations, including potentially increased costs of the road if it had to be made longer to avoid or relocate a stream crossing, or if additional field inspection or survey were required. In addition, some of the soils, slope, and hydrological criteria listed in the BMP might not exist in selected instances. Finally, rerouting to find the proper site criteria might force the road into valuable wildlife habitat areas. However, it was determined that the limitations generally could be addressed on a site-specific basis and were not significant enough to justify rejection or modification of the BMP.

Finally, the BMP was judged to be responsive to several of the baseline provisions of the Consolidated Permit Regulations. These provisions included 40 CFR 123.92(a)(6)(i), (ii), (vi), and (vii).

Thus, the BMP was found to meet all criteria stated for an "acceptable" rating. No modifications were needed, and this BMP was included in the Handbook.

Literature Cited

Shuldiner, P.W., D.F. Cope, and R.B. Newton. 1979. Ecological effects of highway fills on wetlands. National Cooperative Highway Research Program Report 218A. Transportation Research Board, National Research Council. Washington, D.C. 34 p.

Appendix B

Examples of Water Values Classification

Two basic schemes are commonly used by states to assist the land/water manager in determining high water value areas. Many of the BMPs described in the previous pages are often too expensive for general use, but are necessary to protect fish, wildlife, and water resources in those situations where resources are of special concern for their ecological, recreational, or water supply value. Several states have developed schemes to assist the managers of lands and waters in determining which of the waters are of special concern.

Identification of waters needing special attention can often be found in States' nonpoint source (208) plans. Copies of the plans, if they exist, can be obtained from the State water resources agency or other State agencies charged with administering the 208 program. The designations found in them can be used by the road planner/manager to determine what potential water crossings are of concern, and thus which require a stronger system of BMPs.

Other States have Forest Practices Acts, usually administered by the State's Forestry Departments, but interfaced with the nonpoint source program. In those cases, the Forestry Department often has the information needed to assist the road planner in identifying important water value areas.

In some cases, presence of a recreational fishery (Kelley and Committee, no date), designation as a trout stream, existence of a municipal watershed (Miller et al. 1979), and/or other criteria are used to determine whether or not a body of water deserves special attention. These areas are presented as a list promulgated through the 208 process.

In other cases, states use standardized classification schemes (Table 11; Oregon Department of Forestry 1980, Washington Forest Practice Board 1976). In these instances, the classification process is conducted by trained biologists.

Table 11. Comparison of Oregon's (Oregon Department of Forestry 1980) and Washington's (Washington Forest Practice Board 1976) water classification schemes.

Relative Water Value Rating and Level of Protection	Washington	Oregon
High ↓	"Type 1 Water" means all waters, within their ordinary high-water mark, as inventoried pursuant to state regulations. "Type 2 Water" shall mean segments of natural waters which are not classified as Type 1 Water and have a high use and are important from a water quality standpoint for: (a) Domestic water supplies, (b) Public recreation, (c) Fish spawning, rearing, or migration or wildlife uses, or (d) Are highly significant to protect water quality. "Type 3 Water" shall mean segments of natural waters which are not classified as Type 1 or 2 Water and have a moderate to slight use and are moderately important from a water quality standpoint for: (a) Domestic use, (b) Public recreation, (c) Fish spawning, rearing, or migration or wildlife uses, or (d) Have moderate value to protect water quality.	"Class I Streams" means waters which are valuable for domestic use, are important for angling or other recreation, and/or used by significant numbers of fish for spawning, rearing, or migration routes. Stream flows may be either perennial or intermittent during parts of the year.
	"Type 4 Water" shall mean segments of natural waters which are not classified as Type 1, 2, or 3. Their significance lies in their influence on water quality downstream in Type 1, 2, and 3 Waters. These may be perennial or intermittent. "Type 5 Water" means all other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, ponds, and natural sinks. Drainage ways having short periods of spring runoff are considered to be Type 5 Waters.	"Class II Streams" means any headwater streams or minor drainages that generally have limited or no direct value for angling or other recreation. They are used by only a few, if any, fish for spawning or rearing. Their principal value lies in their influence on water quality or quantity downstream in Class I Waters. Stream flow may be either perennial or intermittent.
Low		

Examples of Water Values Classification

References

* Kelly, A.W. and Committee. No date. Silvicultural water quality management plan. West Va. Dept. Nat. Res., 208 Silvicultural Tech. Action Committee. Charleston. 50 p. + 5 Exhibits.

* Miller, S., C.M. Pennock, and Committee. 1979. Best management practices handbook; forestry. Virginia State Water Control Board, Planning Bulletin 317. Richmond.

* Oregon Department of Forestry. 1980. Field guide to Oregon forest practice rules; seventh revision. Salem, Oregon. 59 p.

* Washington Forest Practice Board. 1976. Washington forest practice rules and regulations. Olympia. 54 p.

*cited in text

Appendix C

Planting Prescriptions for Michigan

The following tables and figures present additional information to assist planners and biologists for the test state of Michigan to implement the seeding and planting (4.4) BMP. The information provides species, seed mixture, and planting dates for vegetation establishment by subdividing the state into various ecological zones. This information was excerpted from segments of the USDA Soil Conservation Service (1978) Michigan technical guide for critical area planting and Beckett Jackson Raeder, Inc. (1979).

Literature Cited

Beckett Jackson Raeder, Inc. 1979. Michigan soil erosion and sedimentation control guidebook. Michigan Dept. Nat. Resources, Div. of Land Resource Programs. Lansing. 108 p.

USDA Soil Conservation Service. 1978. Critical area planting. Technical Guide, Section IV, 342-1. State Office, East Lansing, Michigan.

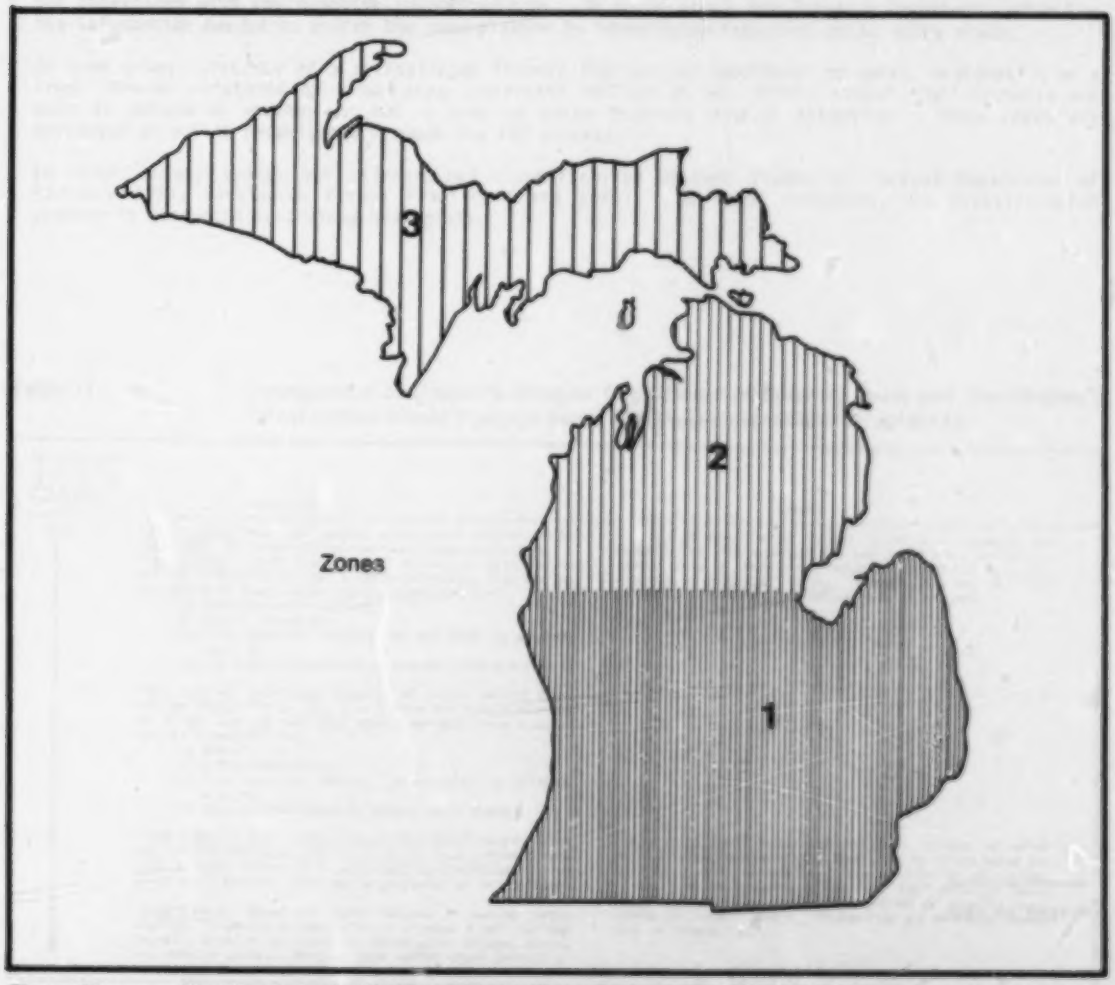

Figure 59 Planting zones in Michigan (Illustration adapted from USDA Soil Conservation Service 1978).

Planting Prescriptions for Michigan

Table 12. **Minimum seeding mixtures in pounds per 1000 sq. ft. for long term vegetative cover for steep areas, ditch banks, cuts and fills in Michigan (USDA Soil Conservation Service 1978).**

	SCS Seed Mixture Number									
	4	6	7	8	9	10	13	16	18	19
Applicable Soil Type(s)[1]	1,2	1	2,3	2,3,4	2,3	4,5	3,4	4,5	5	2,3
SPECIES										
Creeping red fescue	1.0	0.6		0.5						
Perennial ryegrass	2	0.2							0.2	
Kentucky bluegrass				0.2						
Redtop				0.03				0.03	0.05	
Reed canarygrass						0.3		0.3		
Seaside bentgrass							0.03			
Smooth bromegrass							0.4			
Tall fescue		0.5		0.5	0.3		0.4			
Timothy			0.1	0.05				0.1		
Birdsfoot trefoil[3]			0.3	0.3						0.3
Crownvetch[3]					0.4					

[1]Soil types are as follows:
1. Well and moderately well-drained sand and loamy sand (coarse-textured soils).
2. Well and moderately well-drained moderately coarse to moderately fine textured soils (sandy loam, loam silt loam, and clay loam).
3. Well and moderately well-drained clay and silty clay (fine-textured soils).
4. Somewhat poorly drained or poorly drained soils without artificial drainage.
5. Organic soils.

[2]0.15 pounds of ryegrass may be added to this mixture on erodible sites or other areas where quick cover is essential.

[3]Legume seeds should be innoculated in accordance with manufacturer's recommendations.

Table 13. **Seeding dates for long-term vegetative cover in Michigan (USDA Soil Conservation Service 1978).**

ZONES	WITH IRRIGATION AND/OR MULCH	WITHOUT IRRIGATION OR MULCH
Lower Peninsula, South of U. S. 10 (Land Resource Areas 97, 98, 99, and 111) (Zone 1)	Apr. 20 to Oct. 1	Apr. 20 to May 20
	Nov. 1 to freeze-up*	Aug. 10 to Oct. 1
Lower Peninsula, North of U. S. 10 (Land Resource Areas 94S, 95 and 95) (Zone 2)	May 1 to Sept. 20	May 1 to June 10
	Oct. 25 to freeze-up*	Aug. 1 to Sept. 20
Upper Peninsula (Land Resource Areas 92, 93, 94-N) (Zone 3)	May 1 to Sept. 10	May 1 to June 15
	Oct. 20 to freeze-up*	Aug. 1 to Sept. 20

*A "dormant seeding" may be made in late fall to germinate in spring. Dormant seedings must be mulched. Do not seed when ground is frozen or snow-covered. Do not use a dormant seeding on grassed waterways.

Appendix C

Table 14. **Trees and shrubs for critical area planting in Michigan (USDA Soil Conservation Service 1978).**

Soil Condition	Trees[1]	Shrubs
1. Well and moderately well-drained sand and loamy sand (coarse-textured soils)	Austrian pine Jack pine Red pine White pine Scotch pine Black locust Cottonwood	Autumn olive Hawthorn Crabapple Tatarian honeysuckle Staghorn sumac Serviceberry
2. Well and moderately well-drained moderately coarse to moderately fine-textured soils (sandy loam, loam, silt loam, and clay loam)	Red pine White pine Cottonwood Norway spruce Jack pine White spruce Black locust Sugar maple	Gray dogwood Autumn olive Crabapple
3. Well and moderately well-drained clay and silty clay (fine-textured soils)	White pine Norway spruce Black locust White spruce Sugar maple Red pine Cottonwood	Silky dogwood Tatarian honeysuckle Autumn olive Crabapple

[1]For other species, refer to Section II-H of the SCS Technical Guide.

Table 15. **Temporary vegetative cover for critical area planting in Michigan (USDA Soil Conservation Service 1978).**

Planting date by zone				Amount	
Zone 1[1]	Zone 2[2]	Zone 3[3]	Kind of seed	Per 1000 Sq.Ft.	Per Acre
Apr. 1 to Sept. 15	Apr. 15 to Aug. 1	May 1 to Aug. 1	Oats, barley	2 lb.	3 bu.
			or Perennial ryegrass	1/2 lbs.	20-25 lbs.
June-July	June-July	Not rec.	Sudangrass	1 lbs.	30-40 lbs.
Aug. 1 to Oct. 15	Aug. 1 to Oct. 10	Aug. 1 to Oct. 1	Rye or	3 lbs.	2-3 bu.
			Perennial ryegrass	1/2 lbs.	20-25 lb.
Sept. 20 to Oct. 15	Sept. 10 to Oct. 10	Sept. 1 to Oct. 1	Wheat	3 lbs.	2-3 bu.

[1]Lower Peninsula, South of U.S. 10 (Land Resource Areas 97, 98, 99, and 111)
[2]Lower Peninsula, North of U.S. 10 (Land Resource Areas 94-S, 96)
[3]Upper Peninsula (Land Resource Area 92, 93, 94-N)

Table 16. Other ground covers for critical area planting in Michigan (USDA Soil Conservation Service 1978).

Where Applicable: On erosive sites where low-growing plants are desirable. Use in masses to large areas, steep slopes, and shaded spots. Small plants such as bugleweed should be set four to six inches apart; set larger plants like junipers about three to four feet apart. Select adapted plants from the following Chart:

Plant	Height (inches)	Sun	Partial Shade	Shade	Soil	Comments
Bugleweed (carpet bugle) (Ajuga reptans)	4 to 8	X	X	X	most soils	One of the best perennials; spreads rapidly. Parent plant has deep green foliage, blue flowers. Gaiety & Metallica Crispa varieties have bronze-purple leaves. Silver Beauty's foliage is cream & light green. Alba is white-flowered.
English Ivy (Hedera helix)	6 to 8	X	X	X	rich, well-drained	Semievergreen to evergreen; covers large or small areas. Look for improved varieties: Baltic, Thorndale, Wilson & others.
Japanese Spurge (Pachysandra terminalis)	up to 6		X	X	fertile moist	Universally popular evergreen herb, especially good in the Northeast. Some plants have small, spiked white flowers sometimes followed by white berries in the fall. Improved forms: Green Carpet, Silver Edge.
Juniper (Juniperus horizontalis)	12 to 18	X	X		dry areas	Creeping, soft-textured plant; light green to steel blue needles frequently turn purple in winter. Waukegan variety is good; Japanese garden is very compact.
Juniper (J. sabina tamariscifolia)	up to 24	X	X		dry areas	Sometimes called Tamarix Savin Juniper. Needlelike silver-green leaves. A good spreader for slopes; use as foreground for deciduous trees or complete ground cover.
Lily-of-the-Valley (Convallaris majalis)	6 to 10		X	X	rich, moist	Fragrant white bell-like flowers; Rosea variety has light purplish-pink flowers.
Periwinkle (myrtle) (Vinca minor)	up to 6		X	X	moist, well-drained	Almost universally used, dislikes humid conditions. Good on slopes, level land or as a backdrop for bulbs. Bowles, a superior variety, has glossier leaves, larger blue flowers; Golden Bowles has gold & yellow foliage with white flowers.
Stonecrop, Goldmoss (Sedum acre)	up to 4	X	X		stony, sandy dry	Mats of tiny foliage, good between stepping stones and in crevices. Spreads rapidly and can become a weed in grass. The sedum variety, Dragon's Blood, is known for its reddish-bronze inch-high foliage & carmine flowers.
Sedum album	up to 4	X	X		sandy, well-drained	Forms mats of attractive dark-green to red foliage on creeping stems. Not as likely to invade grass areas as stonecrop.

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Appendix D

Planting Prescriptions for Colorado

The following tables and figures present additional information to assist planners and biologists for the test state of Colorado to implement the seeding and planting (4.4) BMP. The information provides species, seed mixtures, and planting dates for vegetation establishment by subdividing the state into various ecological zones. This information was excerpted from segments of the USDA Soil Conservation Service (1981) Colorado technical guide for critical area planting.

Literature Cited

USDA Soil Conservation Service. 1981. Critical area planting. Technical Guide, Section IV, 342. Denver, Colorado.

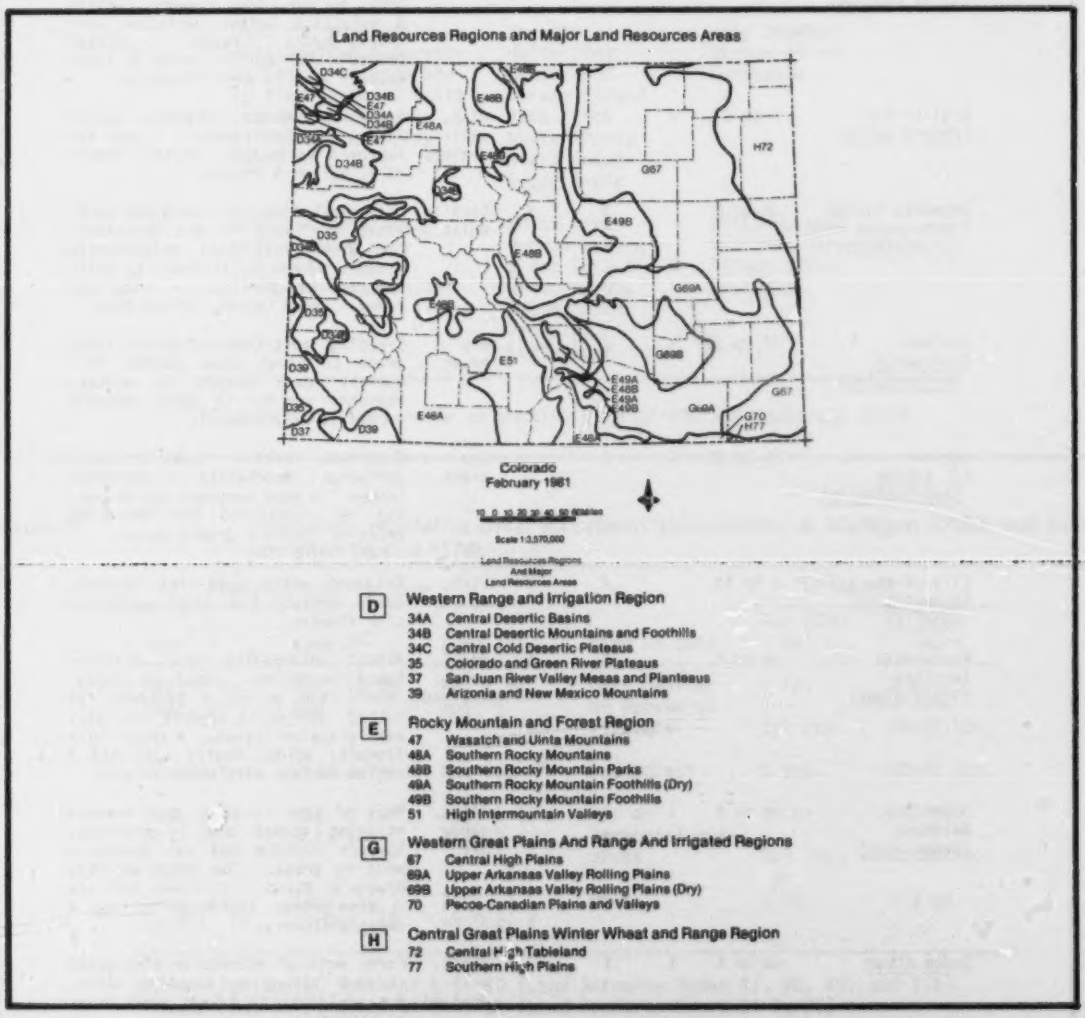

Figure 60 **Planting zones in Colorado (Illustration adapted from USDA Soil Conservation Service 1981).**

Planting Prescriptions for Colorado

Table 17. **Seeding dates for critical area plantings in Colorado (USDA Soil Conservation Service 1981).**

MLRA*	Cool Season Plants		Warm Season Plants	
	Dormant-Spring	Summer	Dormant-Spring	Summer
D-34A, B, C, D-35, D-37, D-39	Oct 15-Apr 30	Jul 15-Aug 31	Oct 15-Apr 30	Jun 15-Jul 15
E-48A, E-48B, E-47	Oct 1-Apr 30	Jun 15-Jul 15[1]	Oct 1-Apr 30	Jun 15-Jul 15
E-49A, E-49B	Oct 15-May 15	Aug 1-Aug 31[2]	Oct 15-May 31	
E-51	Oct 15-Apr 15	Jun 15-Jul 15	Oct 15-Apr 15	Jun 15-Jul 15
G-67 So. Colo. G-70, H-77	Nov 1-Apr 30	Aug 15-Sep 15[2]	Nov 1-May 31	
G-67 No. Colo. H-72	Oct 15-May 15	Aug 15-Sep 15[2]	Nov 1-May 31	
G-69A, G-69B	Nov 1-Apr 30	Aug 15-Sep 15[2]	Nov 1-May 31	

*Major Land Resource Area

[1]Applicable to MLRA E-48A and E-48B on eastern slope of Rocky Mountains.

[2]Applicable to irrigated sites.

Appendix D

Table 18. Perennial grasses and forbs for critical area plantings in Major Land Resource Areas D-34A, D-34B, D-34C, D-37 and D-39 in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Uplands Precipitation <12 Soils 2/ L	Uplands Precipitation <12 Soils 2/ C	Uplands Precipitation >12 Soils L	Uplands Precipitation >12 Soils C	Lowlands 1/ Precipitation <12 Soils L	Lowlands 1/ Precipitation <12 Soils C	Lowlands 1/ Precipitation >12 Soils L	Lowlands 1/ Precipitation >12 Soils C	Adaptability Ratings 3/ Ease of Establish.	Adaptability Ratings 3/ Rate of Spread	Adaptability Ratings 3/ Salt Tolerance
Fairway wheatgrass (Agropyron cristatum)		B	16			X	X			X		4	2	2
Crested wheatgrass (Agropyron desertorum)	Nordan	B	20			X	X	X		X		4	2	2
Tall wheatgrass (Agropyron elongatum)	Largo Jose	B	48							X	X	4	1	5
Beardless wheatgrass (Agropyron inerme)	Whitmar	B	24			X	X					2	2	2
Streambank wheatgrass (Agropyron riparium)	Sodar	S	24			X	X			X	X	4	4	3
Siberian wheatgrass (Agropyron sibiricum)	P-27	B	24			X	X					4	2	2
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	20			X				X	X	3	4	3
Bluebunch wheatgrass (Agropyron spicatum)	4/	B	24			X	X					2	2	2
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	30			X				X		4	3	2
Basin wildrye (Elymus cinereus)	4/	B	48					X		X	X	3	2	3
Russian wildrye (Elymus junceus)	Vinall	B	24	X		X				X		4	1	3
Galleta (Hilaria jamesii)	Viva	S	18	X	X	X	X	X	X	X	X	2	3	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X	X	4	3	3
Indian ricegrass (Oryzopsis hymenoides)	Nezpar Paloma	B	18	best on sands								2	3	2
Rocky Mountain penstemon (Penstemon strictus)	Bandera		18			X						4	2	2
Alkali sacaton (Sporobolus airoides)	4/	B	24					X	X	X	X	2	2	5
Sand dropseed (Sporobolus cryptandrus)	4/	B	20	best on sands								3	3	1

1/ Low-lying areas which receive additional water from higher ground; are gently sloping to flat.
2/ Elevations and soils are general. L = loamy soils; C = clayey soils.
3/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
4/ Seed source from within 150 miles of planting site is recommended.

Planting Prescriptions for Colorado

Table 19. Perennial grasses and forbs for critical area plantings on areas receiving less than 12 inches annual precipitation in Major Land Resource Areas E-48A, E-48B and E-47 in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1/] and Exposure: Slopes over 6:1, North & East		Slopes over 6:1, South & West		Gently sloping to flat		Adaptability Ratings[2/]		
				L	C	L	C	L	C	Ease of Establish.	Rate of Spread	Salt Tolerance
Fairway wheatgrass (Agropyron cristatum)		B	12	X	X	X	X	X	X	5	2	2
Thickspike wheatgrass (Agropyron dasystachyum)	Critana	S	20	best on sand						4	3	3
Beardless wheatgrass (Agropyron inerme)	Whitmar	B	20	X	X	X	X	X	X	2	2	2
Siberian wheatgrass (Agropyron sibiricum)	P-27	B	24	X	X	X	X	X	X	4	2	2
Western wheatgrass (Agropyron smithii)	Rosana Arriba	S	20	X	X			X	X	2	4	3
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	15	X	X	X	X	X	X	5	3	2
Smooth brome (Bromus inermis)	Manchar Lincoln	S	15	X				X	X	4	5	2
Russian wildrye (Elymus junceus)	Vinall	B	24	X	X	X	X	X	X	4	1	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	4	3	3
Indian ricegrass (Oryzopsis hymenoides)	Nezpar	B	18	X	X	X	X	X	X	2	3	2
Rocky Mountain penstemon (Penstemon strictus)	Bandera		18	X	X	X	X	X	X	4	3	2
Alkali sacaton (Sporobolus airoides)	3/	B	24					X 5/	X 5/	2	2	5
Sand dropseed (Sporobolus cryptandrus)	3/	B	20	best on sand						3	3	1
Alsike clover (Trifolium hybridum)			8					X 4/	X 4/	4	4	3
Red clover (Trifolium pratense)			12					X 4/	X 4/	4	4	3

1/ Soils: L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Seed source from within 150 miles of planting site is recommended
4/ Moist lowlands.
5/ Moist, saline lowlands.

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Table 20. Perennial grasses and forbs for critical area plantings on areas receiving 12 to 15 inches annual precipitation in Major Land Resources Areas E-48A, E-48B and E-47 in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1/] and Exposure: Slopes over 6:1, North & East		Slopes over 6:1, South & West		Gently sloping to flat		Adaptability Ratings[2/]		
				L	C	L	C	L	C	Ease of Establish.	Rate of Spread	Salt Tolerance
Fairway wheatgrass (Agropyron cristatum)		B	16	X	X	X	X	X	X	5	2	2
Crested wheatgrass (Agropyron desertorum)	Nordan	B	20	X	X	X	X	X	X	5	2	2
Streambank wheatgrass (Agropyron riparium)	Sodar	S	24	X		X		X	X	4	4	3
Intermediate wheatgrass (Agropyron intermedium)	Amur Tegmar	S	30	X	X	X	X	X	X	4	3	3
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	20	X	X	X	X	X	X	5	3	2
Smooth brome (Bromus inermis)	Manchar Lincoln	S	20	X	X	X	X	X	X	4	5	2
Russian wildrye (Elymus junceus)	Vinall	B	20	X	X	X	X	X	X	4	1	3
Hard fescue (Festuca ovina v. duriuscula)	Durar	B	12	X		X		X		4	3	1
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	4	3	3
Indian ricegrass (Oryzopsis hymenoides)	Nezpar	B	20	X	X	X	X	X	X	2	3	2
Rocky Mountain penstemon (Penstemon strictus)	Bandera		18	X	X	X	X	X	X	4	3	2
Alkali sacaton (Sporobolus airoides)	3/	B	24					X 4/	X 4/	2	2	5
Sand dropseed (Sporobolus cryptandrus)	3/	B	18	best on sand						3	3	1

1/ Soils: L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Seed source from within 150 miles of planting site is recommended.
4/ Moist, saline lowlands.

Table 21. **Perennial grasses and forbs for critical area plantings on areas receiving over 15 inches annual precipitation in Major Land Resource Areas E-48A, E-48B and R-47 in Colorado (USDA Soil Conservation Service 1981).**

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1] and Exposure: Slopes over 6:1, North & East L	North & East C	South & West L	South & West C	Gently sloping to flat L	Gently sloping to flat C	Adaptability Ratings[2]: Ease of Establish.	Rate of Spread	Salt Tolerance
Fairway wheatgrass (Agropyron cristatum)		B	20	X	X	X	X	X	X	5	2	2
Thickspike wheatgrass (Agropyron dasystachyum)	Critana	S	20	X	X	X	X	X	X	4	3	3
Crested wheatgrass (Agropyron desertorum)	Nordan	B	24	X	X	X	X	X	X	5	2	2
Tall wheatgrass (Agropyron elongatum)	Largo Jose	B	48					X 3/	X 3/	5	1	5
Intermediate wheatgrass (Agropyron intermedium)	Tegmar Amur Oahe	S S- S-	30	X	X	X	X	X	X	5	3	2
Streambank wheatgrass (Agropyron riparium)	Sodar	S	30					X	X	4	4	3
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	20	X	X	X	X	X	X	2	4	3
Slender wheatgrass (Agropyron trachycaulum)	Primar	B	30	X	X			X	X	4	2	3
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	30	X	X	X	X	X	X	5	3	2
Redtop (Agrostis alba)		B	24					X 4/	X 4/	4	3	3
Meadow brome (Bromus biebersteinii)	Regar	B	30	X	X	X	X	X	X	5	3	2
Smooth brome (Bromus inermis)	Lincoln Manchar	S	30	X	X	X	X	X	X	4	5	2
Mountain brome (Bromus marginatus)		B	36	X	X	X	X	X	X	5	2	2
Orchardgrass (Dactylis glomerata)	Latar	B	36	X	X			X	X	4	2	2
Russian wildrye (Elymus junceus)	Vinall	B	24					X	X	4	1	3
Tall fescue (Festuca arundinacea)	Alta	B	36	X	X			X	X	4	2	4
Hard fescue (Festuca ovina v. duriuscula)	Durar	B	12	X	X	X	X	X	X	4	3	1
Alfalfa (Medicago sativa)			15	X	X	X	X	X	X	4	2	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	4	3	3
Rocky Mountain penstemon (Penstemon strictus)	Bandera		18	X	X	X	X	X	X	4	3	2
Reed canarygrass (Phalaris arundinacea)		S	48					X	X	4	4	3
Timothy (Phleum pratense)		B	30	X	X			X	X	4	3	1
Kentucky bluegrass (Poa pratensis)		S	20	X	X			X	X	4	4	1
Green needlegrass (Stipa viridula)		B	30				X		X	4	2	1
Alsike clover (Trifolium hybridum)			10	X	X			X 5/	X 5/	4	4	3
Red clover (Trifolium pratense)			12	X	X			X	X	4	4	3
Hairy vetch (Vicia villosa)	Madison		24	X	X	X	X	X	X	3	2	1

1/ Soils: L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Moist, saline lowlands.
4/ Moist lowlands.
5/ Tolerates poorly drained soils.

Table 22. Perennial grasses and forbs for critical area plantings on non-irrigated sites in Major Land Resource Areas E-49A and E-49B in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1] and Exposure: Slopes over 6:1, North and East			Slopes over 6:1, South and West			Gently sloping to flat			Adaptability Ratings[2]: Ease of Establish.	Rate of Spread	Salt Tolerance
				S	L	C	S	L	C	S	L	C			
Fairway wheatgrass (Agropyron cristatum)		B	10	X	X	X	X	X	X	X	X	X	5	3	2
Tall wheatgrass (Agropyron elongatum)	Largo Jose	B	48							X	X	X	5	1	5
Intermediate wheat-grass 4/5/ (Agropyron intermedium)	Amur Oahe	S-	30	X	X	X	X	X		X	X	X	5	3	2
Streambank wheatgrass (Agropyron riparium)	Sodar	S	15	X	X	X	X	X	X	X	X	X	4	4	3
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	18	X	X	X	X	X		X	X	X	2	4	3
Pubescent wheatgrass[5] (Agropyron trichophorum)	Luna	S-	30	X	X	X	X	X	X	X	X	X	5	3	2
Big bluestem (Andropogon gerardii)	Kaw	S-	48	X	X					X	X		3	3	1
Sand bluestem (Andropogon hallii)	Elida	S	48	X			X			X			4	4	1
Sideoats grama (Bouteloua curtipendula)	Vaughn Butte	B	15	X	X	X	X	X	X	X	X	X	5	3	1
Blue grama (Bouteloua gracilis)	Lovington	B	12	X	X	X	X	X	X	X	X	X	2	2	2
Smooth brome[5] (Bromus inermis)	Manchar Lincoln	S	30	X	X	X	X	X	X	X	X	X	4	5	2
Buffalograss (Buchloe dactyloides)	3/	S	4								X	X	2	5	2
Prairie sandreed (Calamovilfa longifolia)	3/	S	36	X	X		X	X		X	X		3	5	1
Hard fescue[4/5] (Festuca ovina v. duriuscula)	Durar	B	15		X			X			X		5	4	2
Alfalfa[5] (Medicago sativa)			15	X	X	X	X			X	X	X	4	2	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X	X	X	5	3	3
Indian ricegrass (Oryzopsis hymenoides)	Paloma	B	16	X	X		X	X		X	X		2	3	2
Rocky Mountain penstemon (Penstemon strictus)	Bandera		18	X	X		X	X		X	X		4	3	2
Kentucky bluegrass[4/5] (Poa pratensis)		S	8	X	X	X	X	X		X	X	X	4	4	1
Little bluestem (Schizachyrium scoparium)	Pastura	B	30	X	X		X	X	X	X	X		4	2	1
Sand dropseed (Sporobolus cryptandrus)	3/	B	15	X	X	X	X	X	X	X	X	X	4	3	1
Green needlegrass (Stipa viridula)		B	24		X	X		X			X	X	4	2	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Seed source from within 150 miles of planting site is recommended.
4/ Above 6,000 feet.
5/ Primarily adapted to MLRA E-49B and the higher precipitation areas of E-49A.

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Table 23. Perennial grasses and forbs for critical area plantings on non-irrigated sites in Major Land Resource Area E-51 in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1] & Moisture: Depth to Water Table: Less than 24 inches			Over 24 inches			Adaptability Ratings[2]		
				S	L	C	S	L	C	Ease of Establish.	Rate of Spread	Salt Tolerance
Fairway wheatgrass (*Agropyron cristatum*)		B	15				X	X	X	5	2	2
Thickspike wheatgrass (*Agropyron dasystachyum*)	Critana	S	20				X	X		4	3	3
Tall wheatgrass (*Agropyron elongatum*)	Largo Jose	B	48	X	X	X		X 3/		4	1	5
Streambank wheatgrass (*Agropyron riparium*)	Sodar	S	24	X	X	X		X		4	3	3
Siberian wheatgrass (*Agropyron sibiricum*)	P-27	B	20				X	X	X	4	2	2
Western wheatgrass (*Agropyron smithii*)	Rosana Arriba	S	20					X	X	2	4	3
Slender wheatgrass (*Agropyron trachycaulum*)	Primar	B	30		X	X		X 4/	X 4/	4	2	3
Pubescent wheatgrass (*Agropyron trichophorum*)	Luna	S-	24				X	X	X	5	3	2
Blue grama (*Bouteloua gracilis*)		B	10					X	X	2	2	2
Russian wildrye (*Elymus junceus*)	Vinall	B	24		X	X		X	X	4	1	3
Tall fescue (*Festuca arundinacea*)	Alta	B	36	X	X	X				4	2	4
Yellow sweetclover (*Melilotus officinalis*)			36	X	X	X		X	X	4	3	3
Indian ricegrass (*Oryzopsis hymenoides*)		B	16				X	X		2	3	2
Reed canarygrass (*Phalaris arundinacea*)		S	48	X	X	X		X 4/	X 4/	4	4	3
Alkali sacaton (*Sporobolus airoides*)		B	24	X	X	X		X 4/	X 4/	2	2	5
Sand dropseed (*Sporobolus cryptandrus*)		B	20				X	X		4	3	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 - good; 5 = excellent.
3/ Moist, saline sites.
4/ Moist sites.

Appendix D

Table 24. Perennial grasses and forbs for critical area plantings in Major Land Resource Areas G-70, H-77 and southern part of G-67 or areas receiving less than 15 inches annual precipitation in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1/] and Exposure: Slopes over 6:1, North & East			Slopes over 6:1, South & West			Gently Sloping to flat			Adaptability Ratings[2/]		
				S	L	C	S	L	C	S	L	C	Ease of Establish.	Rate of Spread	Salt Tolerance
Thickspike wheatgrass (Agropyron dasystachyum)				X			X			X			4	3	3
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	12		X	X					X	X	2	4	3
Sand bluestem (Andropogon hallii)	Elida	S	48	X			X			X			4	4	1
Sideoats grama (Bouteloua curtipendula)	Vaughn Butte	B	15	X	X	X	X	X	X	X	X	X	5	3	1
Blue grama (Bouteloua gracilis)	Lovington	B	12	X	X	X	X	X	X	X	X	X	2	2	2
Buffalograss (Buchloe dactyloides)	4/	S	4								X	X	2	5	2
Prairie sandreed (Calamovilfa longifolia)	Goshen	S	48	X			X			X			3	5	1
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X	X	X	5	3	3
Switchgrass (Panicum virgatum)	Grenville	S-	30	X	X					X	X	X	4	2	4
Little bluestem (Schizachyrium scoparium)	Pastura	B	24	X	X	X				X	X		4	2	1
Alkali sacaton[3/] (Sporobolus airoides)	4/	B	24								X	X	2	2	5
Sand dropseed (Sporobolus cryptandrus)	4/	B	20	X			X			X			4	3	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 - good; 5 = excellent.
3/ Moist lowlands.
4/ Seed source from within 150 miles of planting site is recommended.

Table 25. **Perennial grasses and forbs for critical area plantings in northern part of Major Land Resource Area G-67 or areas in G-67 receiving more than 15 inches annual precipitation in Colorado (USDA Soil Conservation Service 1981).**

Species	Recommended Varieties	B-Bunch S-Sod-former	Mature height (inches)	Soils[1] and Exposure: Slopes over 6:1, North & East			Slopes over 6:1, South & West			Gently sloping to flat			Adaptability Ratings[2]: Ease of Establish.	Rate of Spread	Salt Tolerance
				S	L	C	S	L	C	S	L	C			
Fairway wheatgrass[3] (Agropyron cristatum)		B	12		X	X					X	X	5	2	2
Thickspike wheatgrass (Agropyron dasystachyum)	Critana	S	20	X	X		X			X	X		4	3	3
Crested wheatgrass[3] (Agropyron desertorum)	Nordan	B	12		X	X					X	X	5	2	2
Tall wheatgrass[4] (Agropyron elongatum)	Largo	B	48								X	X	5	1	5
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	12		X	X		X	X		X	X	2	4	3
Pubescent wheatgrass[3] (Agropyron trichophorum)	Luna	S-	30		X	X					X	X	5	3	2
Sand bluestem (Andropogon hallii)	Elida	S	48	X			X			X			4	4	1
Sideoats grama (Bouteloua curtipendula)	Vaughn Butte	B	15	X	X	X	X	X	X	X	X	X	5	3	1
Blue grama (Bouteloua gracilis)	Lovington	B	12		X	X	X	X	X	X	X	X	2	2	2
Smooth brome (Bromus inermis)	Manchar Lincoln	S	24		X	X		X	X		X	X	4	4	2
Buffalograss (Buchloe dactyloides)	5/	S	4								X	X	2	5	2
Prairie sandreed (Calamovilfa longifolia)	Goshen	S	48	X			X			X			3	5	1
Russian wildrye (Elymus junceus)	Vinall	B	24								X	X	4	1	3
Sand lovegrass[3] (Eragrostis trichodes)	Nebraska 27	B	24	X			X			X			4	3	1
Alfalfa[3] (Medicago sativa)	Ladak		15	X	X	X	X	X	X	X	X	X	4	2	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X	X	X	5	3	3
Switchgrass (Panicum virgatum)	Grenville	S-	30	X	X		X			X	X	X	4	2	4
Little bluestem (Schizachyrium scoparium)	Pastura	B	24	X	X	X	X	X	X	X	X	X	4	2	1
Alkali sacaton[4] (Sporobolus airoides)	5/	B	24								X	X	2	2	5
Sand dropseed (Sporobolus cryptandrus)	5/	B	20	X	X		X	X		X	X		4	3	1
Green needlegrass (Stipa viridula)		B	24		X	X		X	X		X	X	4	2	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Recommended for sites north of U. S. Highway No. 24
4/ Moist lowlands.
5/ Seed source from within 150 miles of planting site is recommended.

Table 26. Perennial grasses and forbs for critical area plantings on non-irrigated sites in Major Land Resource Areas G-69A and G-69B in Colorado (USDA Soil Conservation Service 1981).

Species	Recommended Variation	B-Bunch S-Sod-Former	Mature height (inches)	Soils, Exposure and Topographic Position of Site 1/										Adapt. Rat'g. 2/		
				Upland Sites				Lowland Sites						Ease of Establish.	Rate of Spread	Salt Tolerance
				Slopes >6:1												
				North & East		South & West		Slopes < 6:1		Saline, Alkaline		Non-saline Non-alkal.				
				S	LC	S	LC	S	LC	Moist Sites	Dry Sites	Moist Sites	Dry Sites			
Tall wheatgrass (Agropyron elongatum)	Large Jose	B	48							X		X		5	1	5
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosana	S	15						X	X	X	X	X	2	1	3
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	24							X		X		5	3	2
Sand bluestem (Andropogon hallii)	Elida	S	48	X		X		X						4	4	1
Yellow bluestem (Andropogon ischaemum)	Ganado	B	36	X	X	X	X	X	X					3	3	1
Sideoats grama (Bouteloua curtipendula)	Vaughn	B	12	X	X	X	X	X	X					5	3	1
Blue grama (Bouteloua gracilis)	Lovington Hachita	B	10	X	X	X	X	X	X					2	2	2
Smooth brome (Bromus inermis)	Lincoln	S	30									X		4	5	2
Buffalograss (Buchloe dactyloides)	3/	S	4						X			X	X	2	5	2
Orchardgrass (Dactylis glomerata)		B	30									X		4	2	2
Russian wildrye (Elymus junceus)	Vinall	B	30						X					4	1	3
Tall fescue (Festuca arundinacea)	Alta	B	30							X		X		4	2	4
Galleta (Hilaria jamesii)	Viva	S	20		X		X		X		X		X	5	3	2
Alfalfa (Medicago sativa)	Ladak		15							X		X		4	2	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X		X		5	3	3
Switchgrass (Panicum virgatum)	Granville	S-	30	X				X		X		X		4	2	4
Reed canarygrass (Phalaris arundinacea)	Soreed	S	48							X		X		4	4	2
Little bluestem (Schizachyrium scoparium)	Pastura	B	12	X				X				X		4	2	1
Indiangrass (Sorghastrum nutans)	Llano	S-	96					X				X		4	3	1
Alkali sacaton (Sporobolus airoides)	3/	B	24							X				2	2	5
Sand dropseed (Sporobolus cryptandrus)	3/	B	14	X		X	X	X					X	4	2	1
Strawberry clover (Trifolium fragiferum)			8							X		X		3	3	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Seed source from within 100 miles of planting site to recommended.

Table 27. **Perennial grasses and forbs for critical area plantings in Major Land Resource Area H-72 in Colorado (USDA Soil Conservation Service 1981).**

Species	Recommended Varieties	B-Bunch S-Sod-Former	Mature height (inches)	Soils[1] and Exposure: Slopes over 6:1, North and East			Slopes over 6:1, South and West			Gently Sloping to Flat			Adaptability Ratings[2]: Ease of Establish.	Rate of Spread	Salt Tolerance
				S	L	C	S	L	C	S	L	C			
Fairway wheatgrass (Agropyron cristatum)		B	10		X	X		X	X		X	X	5	3	2
Tall wheatgrass (Agropyron elongatum)	Large Jose	B	40								X	X	5	1	5
Intermediate wheatgrass (Agropyron intermedium)	Beer	S-	30		X	X		X	X		X	X	5	3	2
Western wheatgrass (Agropyron smithii)	Arriba Barton Rosara	S	15		X	X		X	X		X	X	2	4	3
Pubescent wheatgrass (Agropyron trichophorum)	Luna	S-	30		X	X		X	X		X	X	5	3	2
Big bluestem (Andropogon gerardi)	Niu	S-	80	X	X					X	X		3	3	3
Sand bluestem (Andropogon hallii)	Woodward Elida	S	80	X			X			X			4	4	1
Sideoats grama (Bouteloua curtipendula)	Butte	B	25	X	X	X	X	X		X	X	X	5	3	1
Blue grama (Bouteloua gracilis)	Lovington	B	12	X	X	X	X	X	X	X	X	X	2	2	2
Buffalograss (Buchloe dactyloides)	3/	S	4								X	X	2	5	2
Prairie sandreed (Calamovilfa longifolia)	Goshen	S	48	X			X			X			3	5	1
Sand lovegrass (Eragrostis trichodes)	Nebraska 27	B	24	X			X			X			4	3	1
Alfalfa (Medicago sativa)	Ladak		15	X	X	X	X	X		X	X	X	4	2	3
Yellow sweetclover (Melilotus officinalis)			36	X	X	X	X	X	X	X	X	X	5	3	3
Switchgrass (Panicum virgatum)	Nebraska 28	S-	50	X			X			X	X	X	4	2	4
Little bluestem (Schizachyrium scoparium)	Pastura	B	30	X	X	X	X			X	X	X	4	2	1
Indiangrass (Sorghastrum nutans)	Holt Llano	S-	60	X			X			X	X		4	3	1
Alkali sacaton[4] (Sporobolus airoides)	3/	B	30								X	X	2	2	5
Sand dropseed (Sporobolus cryptandrus)	3/	B	15	X	X		X	X		X	X		4	3	1
Green needlegrass (Stipa viridula)		B	24		X	X		X	X		X	X	4	2	1

1/ Soils: S = sandy; L = loamy; C = clayey.
2/ Adaptability ratings: 1 = poor; 2 = fair; 3 = moderate; 4 = good; 5 = excellent.
3/ Seed source from within 100 miles of planting site is recommended.
4/ Moist, saline lowlands.

Table 28. Woody plants for critical area plantings in Colorado (USDA Soil Conservation Service 1981).

Species	D-34A D-34B D-34C D-37 D-39	D-35	E-47 E-48A E-48B	E-49A E-49B	E-51	G-67 G-70 H-77	G-69A G-69B	H-72	Growth Characteristic
Louisiana sagewort (Artemisia ludoviciana)	X		X	X		X		X	low shrub
Fourwig saltbush (Atriplex canescens)	X	X	X	X	X	X	X		low shrub
Caragana (Caragana arborescens)	X					X		X	low shrub
Hackberry (Celtis occidentalis)						X		X	tree
Mountainmahogany (Cercocarpus montanus)	X		X	X					shrub
Rubber rabbitbrush (Chrysothamnus nauseosus)	X	X	X	X	X	X	X	X	medium shrub
Bladdersenna (Colutea arborescens)	X		X	X		X		X	medium shrub
Cotoneaster (Cotoneaster acqutifolia)								X	shrub
Hawthorne (Crataegus spp.)			X	X					tall shrub
Russian-olive (Elaeagnus angustifolia)	X	X	X	X	X	X	X	X	tall shrub
Winterfat (Eurotia lanata)	X	X	X	X	X	X			low shrub
New Mexico forestiera (Forestiera neomexicana)	X		X	X		X		X	tall shrub
Oneseed juniper (Juniperus monosperma)	X	X					X		evergreen tree
Rocky Mountain juniper (Juniperus scopulorum)	X		X	X	X	X	X	X	evergreen tree
Eastern redcedar[1/] (Juniperus virginiana)						X	X	X	evergreen tree
Twinberry honeysuckle (Lonicera involucrata)			X	X					medium shrub
Colorado blue spruce (Picea pungens)			X						evergreen tree
Ponderosa pine (Pinus ponderosa)			X	X		X		X	evergreen tree
Shrubby cinquefoil (Potentilla fruticosa)	X		X	X					low shrub
American plum (Prunus americana)			X	X		X	X	X	tall shrub
Bessey sandcherry (Prunus besseyi)				X		X		X	low shrub
Skunkbush sumac (Rhus trilobata)	X	X	X	X	X	X	X	X	low shrub
Golden willow (Salix lutea)			X	X	X			X	tree
Lilac (Syringa vulgaris)			X	X				X	medium shrub
Siberian elm (Ulmus pumila)	X		X	X	X	X	X	X	tree

1/ Adapted below 5,500 feet elevation.

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This Handbook describes 54 best management practices which may be utilized by Federal and State agencies or private landowners and operators in the review of project plans and in the planning, construction, and maintenance of farm and forest roads. Best management practices (BMPs) for planning road and facility layout and design, erosion control, construction and maintenance operations, and restoration to natural conditions, identified through existing State water quality management plans and management practices of Federal agencies, were evaluated as to their environmental, institutional, technical, and econonmic effectiveness. Based on the results of the evaluation, BMPs were modified or augmented with other practices to enhance their overall effectiveness and to provide for protection and propagation of fish and wildlife resources. A discussion of purpose, description, performance and limitations is provided for each BMP, and an approach is developed which guides Handbook users in the selection of BMPs applicable to site-specific situations.

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